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In my previous Editor's message, I commented that in an age where entomologists are becoming a rare species, an adaptive response is to broaden our perspective on entomology to include all science focused on insects. When I first joined the ESO and attended my first ESO conference, Yves Prevost, the previous JESO Editor, asked me in a very friendly manner, whether I had just moved to Ontario. I replied that no, I had been at Brock for five or six years. Yves asked why I had not been at previous meetings, and I replied that I wasn't really sure that I was an entomologist. Yves looked really puzzled, and inquired if I studied insects. When I told him that I studied bees, he responded 'Well, then, you are an entomologist!" I have always treasured that conversation, because it represented to me such a broad and welcoming perspective in defining entomology. This perspective has also guided me as Editor of JESO – all sorts of insect science are welcome at ESO and JESO.

I have been Editor of JESO for about 5 years, starting with Volume 135 (2005) which I co-edited with Yves. I am very pleased that we have managed to accomplish so much in that time. The Journal is back to a regular, annual publication cycle and is now distributed electronically from the ESO website, as well as being published in the more classical paper format. An exciting development is a plan to include JESO in a large electronic journal listing service which will lead to a quantum leap in journal visibility. Although final details are not yet settled, I anticipate that this listing will begin with the current volume. Another exciting development is a plan to have all back issues made available electronically in the near future.

With these developments, JESO will have successfully accomplished the mission that I set out when I first became Editor. I sincerely thank Yves, all the Associate Editors, and the ESO Board for entrusting JESO to me, in the process convincing me, that yes, I am an entomologist. I am very proud of our accomplishments and very gratified that I can pass the baton to a new Editor, knowing that JESO is thriving. I will be co-editing Volume 142 (2011) with a new Editor, who I am sure will guide the Journal through its next developmental phase.

Happy reading!

Miriam H. Richards
Editor

# AERIAL FORAGING AND SEXUAL DIMORPHISM IN BURYING BEETLES (SILPHIDAE: COLEOPTERA) IN A CENTRAL ONTARIO FOREST

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**Abstract**                                    *J. ent. Soc. Ont.* 141: 3-10

Burying beetles (Coleoptera: Silphidae) are commonly sampled on the ground using pitfall traps. Recent work has shown that these beetles also respond to aerial traps baited with carrion. In this study, we sampled the Silphidae of Algonquin Park using traps baited with mouse and bird carrion, and set at 2, 4, and 6 m heights. The most abundant species caught was *Nicrophorus tomentosus*, followed by (in order) *N. defodiens*, *N. sayi*, *Oiceoptoma noveboracense*, *N. pustulatus*, *Necrophila americana*, and *Necrodes surinamensis*. Only *N. tomentosus* showed bait preference, with higher than expected catches at traps baited with mice. Catches differed based on trap height for two species, with most *N. defodiens* being caught in the lower traps (2 m), and all *N. pustulatus* caught at the high traps (6 m). *Nicrophorus tomentosus* males caught in the 6 m traps were significantly larger than males caught in the lower traps, and females caught at all heights. Possible reasons are discussed.

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## Introduction

The carrion beetles (Family Silphidae) have long been a favourite group with collectors and naturalists in North America. There are 30 species of these in North America, and individual species specialize in carrion types based on size and source, ranging from large carcasses such as black bears (Watson and Carlton 2003) (e.g. subfamily Silphinae), to small rodent sized carcasses such as mice and song birds (subfamily Nicrophorinae, the burying beetles; Anderson and Peck 1985). Burying beetles use olfactory cues to locate carcasses, and are able to locate fresh squirrel carcasses several metres distant in a few minutes (Dethier 1947).

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In spite of the attention that this group has attracted in the past, basic life history and niche information is still lacking. For example *Nicrophorus pustulatus* Herchel was only recently determined to be a parasitoid on snake eggs (Blouin-Demers and Weatherhead 2000; Keller and Heske 2001). Regional surveys of extant *Nicrophorus* species do report catching *N. pustulatus* in low numbers (e.g., Anderson 1982; Shubeck et al. 1981), and outside of the range of the black rat snake (Smith et al. 2007). It appears that *N. pustulatus* must utilize some other unknown source of carrion.

What this is may be consistent with the recently observed vertical distribution of *N. pustulatus* in Georgia, where *N. pustulatus* were almost exclusively caught several metres above ground (Ulyshen and Hanula 2007a) in the forest canopy. The canopy habitat includes tree cavities, and these could offer a specialized niche of carrion such as dead nestlings, e.g. squirrels, birds, or bats. Any species differences in how this habitat is exploited should be reflected in catches obtained using carrion baited traps placed at various heights.

In this study, we report on the species composition of Silphidae caught in carrion baited traps placed at three different heights above the ground in Algonquin Park, a large forested region of central Ontario. We also compared trap catches at traps with avian and mammalian baits.

For burying beetles, there are reproductive advantages to size, with larger species and individuals winning fights over carcasses (Otronen 1988; Trumbo 1990). Body size is also related to flight capability. During flight, beetles lose heat due to convection (Merrick and Smith 2004), so that conserving heat would enable longer flights, for example, flight associated with searching or localized dispersal. Such flights would take place at higher levels (Taylor 1974), so we would expect elevated traps to catch these individuals. For the most numerous species caught, *N. tomentosus*, we tested for differences in the size of males and females at each height, reasoning that such size differences might indicate sex biased flight capability associated with dispersal from natal sites.

## Materials and Methods

Silphid beetles were collected during August 2008, in Algonquin Provincial Park, Ontario, Canada. The study site was located along Highway 60, at kilometre 20, Found Lake, Peck Township on the Canadian Shield. The forest was composed of mature trees: maple (predominantly *Acer saccharum* Marsh.), beech (*Fagus grandifolia* Ehrh.), hemlock (*Tsuga canadensis* (L.) Carr.), and birch (*Betula papyrifera* Marsh and *Betula allegheniensis* Britton). The understory was shaded, was easily accessible by foot, and composed mainly of bracken (*Pteridium aquilinum* (L.) Kuhn) with some low density shrubs.

Twenty-four traps were deployed for seven day periods beginning 1, 7, and 14 August 2008, for a total of 72 samples. During sampling, many traps were destroyed by wildlife (bears and raccoons) and wind. If damage occurred early in the sampling week, traps were re-installed for later collection, so that the length of a trapping period varied for some traps. Fourteen ruined traps could not be replaced. For each sampling week, traps were positioned in a grid or block comprised of three rows of eight traps per row. The rows

were spaced 15 m apart, with traps in each row spaced 10 m. Traps were placed at 2, 4, and 6 m above ground, with 6 m traps placed in the upper trunk zones but just below the canopy level. Trap height and bait type were randomized over the 24 possible locations in each block (there were eight possible X and three possible Y coordinates), so that there were four traps for each bait type at each height in the block.

Traps were constructed from 2 L plastic soda pop bottles with a 6 cm diameter hole cut into the middle of one side to allow beetles to enter the traps. Bait was wrapped in cheese cloth and hung in each bottle by a piece of wire pushed through the lid. The bottom of each trap had a 1.5 cm deep layer of killing solution consisting of 5% dish soap and water (Larsen 2005). A sling shot was used to send a weighted rope over a tree branch to raise and lower traps.

Half the traps were baited with chicken wings and the other half with mice. Frozen domestic mice (*Mus musculus*) were obtained from a reptile feed supply store. The mean weight per mouse was ~ 25 g. Frozen chicken wings were obtained in bulk from the grocery store (mean weight ~ 30 g). Baits were frozen until placed in traps without any prior aging or ripening.

Trapped beetles were preserved in 70% isopropyl alcohol. A sub-sample of 320 *Nicrophorus tomentosus*, about 100 specimens from each height, were sexed and measured for total body length.

Because of the missing data, ANOVA could not be used to test the effects of bait type and trap height on trap catches. Instead, we used a chi-square test (Sokal and Rohlf 1995) to compare the observed to expected total catch frequencies of each species for bait type and trap height. The expected frequencies were determined from the number of trapping days for each category. For example, if 140 individuals of a species were caught over 50 trapping days at traps baited with mice, and 220 were caught over 100 trapping days at traps baited with birds, then the expected frequencies would be (140+220) x (50/150) =120 for mouse traps and (140+220) x (100/150) = 240 for bird traps. Because several comparisons were performed for each test, the critical values of chi-square at a significance level of $\alpha = 0.05$ were adjusted using the Bonferroni method by which $\alpha' = \alpha/k$ (Sokal and Rohlf 1995). For the bait tests and the trap height tests we used k = 7 (number of species tested). Our adjusted critical values for chi-square were 9.94 for 2 degrees of freedom (three trap heights), and 7.33 for 1 degree of freedom (two bait types).

We tested whether there were differences in body length of *N. tomentosus* between males and females at each height using a 2-way ANOVA with trap height and sex as treatments. Statistical tests were done using an Excel spreadsheet and STATISTICA 7 (Statsoft Inc. 2004).

# Results

We caught 2388 Silphidae from 7 species in the traps (Table 1). The most abundant species was *Nicrophorus tomentosus*, accounting for 81% of the total catch. The rarest species was *Necrodes surinamensis*, of which only a single individual was caught, this at 4 m. Members of each species were more abundant in the 2 m traps except for *N.*

TABLE 1. Number of each species of Silphidae captured in carrion baited aerial traps at three different heights in Algonquin Park, Ontario, in August 2008.

| Species | Trap height | | | |
|---|---|---|---|---|
| | 2m | 4m | 6m | Total |
| *Nicrophorus tomentosus* | 863 | 497 | 585 | 1945 |
| *Nicrophorus defodiens* | 191 | 76 | 42 | 309 |
| *Nicrophorus sayi* | 43 | 22 | 25 | 90 |
| *Oiceoptoma noveboracense* | 21 | 7 | 5 | 33 |
| *Nicrophorus pustulatus* | 0 | 0 | 6 | 6 |
| *Necrophila americana* | 4 | 0 | 0 | 4 |
| *Necrodes surinamensis* | 0 | 1 | 0 | 1 |
| Total | 1122 | 603 | 663 | 2388 |

*pustulatus*, which was only found in 6 m traps (Table 1). *N. tomentosus* was the only species for which trap catches differed by bait types, with slightly more caught at mouse baited traps than expected (observed = 856, expected = 791.9; Table 2).

More *N. defodiens* were caught in the lowest traps and more *N. pustulatus* in the higher traps (Table 2). For the other species, observed trap catches at the three heights did not differ from the expected proportions.

The biggest male *N. tomentosus* were caught in the 6 m traps; these were significantly larger than females caught at all heights (Duncan's Multiple Range post-hoc test, 2 metres: p=0.003; 4 metres: p=0.024; 6 metres, p=0.025) and males at 2 metres (2 metres: p=0.012; 4 metres, p=0.07) (Table 3, Fig. 1).
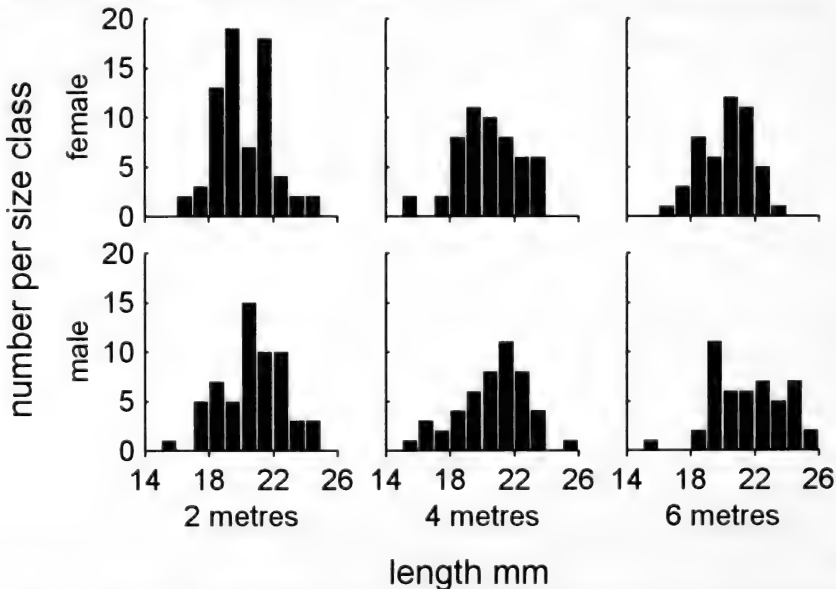


FIGURE 1. Frequency distribution of body lengths of female and male *N. tomentosus* at 2, 4, and 6 metre traps.

TABLE 2. Seasonal totals, per trap means and standard deviations, for each species of Silphidae captured, by bait type (bird and mouse), and trap height (2 m, 4 m, 6 m), in Algonquin Park, Ontario, in August 2008. Treatments were tested using a chi-square test with the critical value based on a Bonferroni adjusted α. Expected frequencies were based on the sum of trapping days for each category (Days).

| Category | (Days) | N | N. defodiens | N. pustulatus | N. sayi | N. tomentosus | N. americana | N. surinamensis | O. noveboracense |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Total catch (Mean, SD) by species | | | |
| bird | (249) | 33 | 179 (5.4, 6.3) | 4 (0.1, 0.55) | 46 (1.4, 2.4) | 1089 (33.0, 36.9) | 0 | 1 (0.03, 0.2) | 26 (0.8, 1.2) |
| mouse | (171) | 23 | 130 (5.7, 5.7) | 2 (0.1, 0.29) | 44 (1.9, 2.6) | 856 (37.2, 45.5)* | 4 (0.2, 0.7) | 0 | 7 (0.3, 0.9) |
| 2m | (176) | 23 | 191 (8.4, 7.5)* | 0 | 43 (1.9, 2.5) | 863 (37.6, 48.2) | 4 (0.2, 0.7) | 0 | 21 (0.9, 1.4) |
| 4m | (116) | 16 | 76 (4.8, 4.2) | 0 | 22 (1.4, 2.4) | 497 (31.1, 27.0) | 0 | 1 (0.1, 0.3) | 7 (0.4, 0.8) |
| 6m | (128) | 17 | 42 (2.4, 2.9) | 6 (0.4, 0.79)* | 25 (1.5, 2.7) | 585 (34.3, 41.0) | 0 | 0 | 5 (0.3, 0.5) |

*significant at α = 0.05, chi-square$_{crit.}$ = 7.33 (1 df) for bait type and 9.94 (2 df) for trap height.

TABLE 3. Mean lengths (mm) of N. tomentosus caught in carrion baited aerial traps at three different heights in Algonquin Park, Ontario, in August 2008.

| Trap height | Males | Females |
|---|---|---|
| | Mean (SD) N, by sex | |
| 2m | 20.25 (2.00) 59 | 19.71 (1.73) 70 |
| 4m | 20.21 (2.17) 48 | 19.96 (1.93) 53 |
| 6m | 21.20 (2.24) 47 | 19.84 (1.62) 47 |

# Discussion

Nicrophorus tomentosus and *N. defodiens* were the most common species captured in this study. Work done in North Carolina has shown that these species are frequently encountered late in the warm season (Trumbo 1990). In southern Ontario, *N. tomentosus* breeds from mid to late summer (Anderson and Peck 1985), with trap catches peaking in late August (Anderson 1982); *N. defodiens* is active from May to early September and has been trapped at similar levels during this period (Anderson 1982). *Nicrophorus sayi*, a spring breeder in Ontario (Anderson 1982) was the third most common species captured, consistent with a previously reported peak in early and late August of teneral adults (Anderson 1982).

Only *N. tomentosus* showed any bait preference, with a minor preference for traps with mice. For the *Nicrophorus* spp., small carrion would include dead fledglings as well as dead rodents. In terms of possible tree hole exploitation, both types of carrion would be present. Generally, Silphinae are attracted to larger carrion (Anderson and Peck 1985).

## Height Preference

*Nicrophorus* were caught at all heights except *N. pustulatus* and *N. defodiens*. *Nicrophorus defodiens* is a small species, and it compensates for this competitive disadvantage by being able to locate carcasses quicker than its larger competitors, such as *N. orbicollis* Say (Trumbo and Bloch 2002). That it was caught less often in the higher traps may reflect a possible decreased flight height due to its smaller size rather than its inability to find the bait.

Our results support our initial reasoning that carrion in the forest canopy might be a suitable specialized niche for exploitation for *N. pustulatus*. Our low catch of 6 individuals is similar to low catches reported in previous studies (Anderson 1982; Robertson 1992). *Nicrophorus pustulatus* does not appear to respond to traps baited with fresh carcasses (Trumbo 1990). However, it has been caught in pitfall traps baited with well-rotted carrion (Trumbo 1990; Anderson 1982).

Catching *N. pustulatus* at elevated traps is consistent with earlier work (Ulyshen and Hanula 2007b). In Ontario, Robertson (1992) caught *N. pustulatus* at 1 m to 2 m. Low catches of *N. pustulatus* at ground level could be due to this species specializing in canopy or nest-cavity habitats rather than specific carrion sources; *N. pustulatus* will breed on dead rodents in lab settings (Robertson 1992).

Nevertheless, black rat snake eggs are the only known wild breeding medium (Smith et al. 2007; Blouin-Demers and Weatherhead 2000), which may explain the generally low numbers caught using mammalian or avian baits. Because of this, the presence of *N. pustulatus* is relevant to the conservation of regionally rare or endangered snake species (Smith et al. 2007) e.g. the black rat snake *Elaphe obsoleta* (Say) in Ontario, a species not found in Algonquin Park (Logier 1970). Our results suggest that surveying for *N. pustulatus* should include aerial traps.

## Sex and Size Dimorphism in *Nicrophorus tomentosus*

For *N. tomentosus*, because males and females both remain with their brood after

covering a carcass, it is unlikely that there is a size advantage for one sex or the other in terms of contests over carcasses. However, there may be a size advantage in terms of flight capability. During flight, beetles lose heat due to convection (Merrick and Smith 2004), so that conserving heat would enable longer flights, for example flight associated with local dispersal. *Nicrophorus tomentosus* is a bumble bee mimic (Fisher and Tuckerman 1986), and is covered in yellow hairs (Milne and Milne 1944), which can contribute to conserving heat and regulating body temperature in *Nicrophorus* spp. (Merrick and Smith 2004).

The female *Nicrophorus tomentosus* we caught were the same size at all trap heights, whereas males caught on 6 m traps were significantly larger than both females and males from lower traps (Table 3). Trumbo (1990), found no difference in the size of male and female *Nicrophorus tomentosus*, nor did we in our lower traps. The larger males were largely present in 6 m traps only (Fig. 1). Sampling at the higher traps would over-represent this group.

## Acknowledgments

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# NATURAL ENEMIES OF THE BEE GENUS *CERATINA* (HYMENOPTERA: APIDAE) IN THE NIAGARA REGION, ONTARIO, CANADA

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## Abstract                              *J. ent. Soc. Ont.* 141: 11-26

*Ceratina dupla* and *C. calcarata* (Hymenoptera: Apidae) are abundant bees
in southern Ontario, commonly nesting in staghorn sumac (*Rhus typhina*),
wild raspberry (*Rubus strigosus*) and teasel (*Dipsacus fullonum*). *Ceratina*
nests were collected from April-September 2008 and parasitized individuals
were reared to adulthood in the laboratory. *Pyemotes* sp. (Pyemotidae) and
*Baryscapus americana* (Eulophidae) were the most common natural enemies,
followed by *Baryscapus* sp., *Axima zabriskiei,* and *Hoplocryptus zoesmairi.*
*Eupelmus vesicularis, Coelopencyrtus* sp. and *Eurytoma* sp. near *apiculae*
were rarely collected. This is the first record of *E. vesicularis* (Eupelmidae)
as a primary host on any member of the family Apidae. New host records are
also reported for *H. zoesmairi* (Ichneumonidae), two different *Baryscapus*
spp. (Eulophidae), *Eurytoma* sp. near *apiculae* (Eurytomidae) and *Pyemotes*
sp. (Pyemotidae) on *C. calcarata* and *C. dupla.* Detailed descriptions of
immature development of the parasitoids, and their preferences for host bee
species and host plant species are provided.

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## Introduction

Parasite–host relationships have been studied for numerous species in a laboratory
setting (Harri et al. 2008; Jervis et al. 2008; Traynor and Mayhew 2005). These studies are
vital to help understand the dynamics of host–parasite interactions, however they often only
involve the most common one or two parasitoids associated with the host under study. In a

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natural setting, hosts may be parasitized by a number of species at varying frequencies, each using different parasitism and developmental strategies at different times. By describing the life history, development and preferences of numerous parasite species attacking one host, a more complete understanding of these interactions is gained.

Bees of the genus *Ceratina* Latreille (often referred to as dwarf carpenter bees), are cosmopolitan, with the subgenus *Zadontomerus* Ashmead being found exclusively in the Western Hemisphere (Michener 2007). The life history of *Ceratina* offers an excellent opportunity to study the development and interactions of parasites with their hosts. All offspring from eggs laid by a single female can be collected together in a nest, thus allowing for observation of how the parasites interact with an individual host, as well as how nest substrate, position in the nest, and interactions with other parasites and the foundress bee occur.

The Niagara Region, Ontario, Canada, is home to two common species of *Ceratina* (*Zadontomerus*): *C. dupla* Say and *C. calcarata* Robertson. Their nests are commonly collected from staghorn sumac (*Rhus typhina* L.), wild raspberry (*Rubus strigosus* Michaux) and teasel (*Dipsacus fullonum* L.; J. Vickruck, unp. data). Both sumac and wild raspberry are native to the region whereas teasel is an obsolete crop plant introduced from Europe, whose flower heads (when the seeds are mature) were once used to raise the knap on wool (Rector et al. 2006). Sumac and raspberry are both perennial plants found at wood margins, differing from teasel which is a biennial weed found in open, generally abandoned agricultural fields.

*Ceratina* in the Niagara region are solitary and univoltine, producing one brood per year and overwintering as newly emerged, unmated adults (J. Vickruck, unpublished data). Emergence and mating typically take place in mid-April, and new nests are founded in May. Nests are not reused from year to year and can only be initiated in twigs with exposed pith. After digging a linear tunnel females begin to forage, forming pollen and nectar provisions into rounded masses upon which a single egg is laid (Grothaus 1962; Johnson 1988; Kislow 1976). Each provision mass and egg is separated from its neighbours by a cell septum formed by the foundress. Once finished provisioning, females sit and guard the nest entrance until the eclosion of their offspring. The newly eclosed adults can either overwinter in their natal nest or disperse to found new hibernacula for the winter (Grothaus 1962; Kislow 1976).

*Ceratina* immatures can be classified into 18 developmental stages which were originally described by Daly (1966) for *C. dallatoreana*. The first eight stages rank the pupa in relation to the size of the pollen ball, after which the immature passes through a pre–pupal stage followed by metamorphosis. The eyes of the pupa then pass from white through to black (five stages), followed by darkening of the body (four stages). In the final stage the black bodied pupa emerges as an adult with milky wings.

Natural enemies of *Ceratina* in the Niagara region include predators, parasites, and parasitoids. Predators consume more than one prey individual in order to complete development. Parasites feed on the host contents but do not consume the entire host before completing development (Godfray 1994). Parasitoids consume a single host in order to complete development (Godfray 1994). Parasitoids were classified as idiobionts or koinobionts, endoparasitoids or ectoparasitoids, and gregarious or solitary. Idiobionts prevent the larva from developing further after initial parasitisation (Askew and Shaw 1986).

Koinobionts do not kill the host until it has reached a certain point in its development, as the parasitoid benefits from the continued life of the host (Askew and Shaw 1986). Ectoparasitoids develop outside the host (although they are often attached to it), while endoparasitoids consume the host internally. In solitary species the parasitoid to host ratio is 1:1, whereas in gregarious parasites multiple individuals develop in one host.

The objectives of this study were to identify and describe the development of the natural enemies of *Ceratina* in the Niagara Region as well as quantify their host and substrate preferences.

## Materials and Methods

### Host nest collections

All parasites were reared from a total of 107 nests of *C. calcarata* and *C. dupla* collected from 14 April to 30 September 2008. Each week at least 15 *Ceratina* nests were collected so that sampling effort was consistent over the season. Supplementary nest collections also took place in June 2009 to aid with final parasite identifications only. The 2009 data are not included in the statistical analysis. All collections took place at the Brock University campus (43.1197, −79.2492), the Glenridge Quarry Naturalization Site (43.1223, −79.2375) and an abandoned old field site near the Welland Canal (43.1479, −79.1811). Nests were collected from sumac, raspberry, and teasel and brought back to the laboratory in early morning to ensure that all occupants were present inside. After being chilled, twigs were carefully split open longitudinally to identify nest contents. Bee species, plant nest substrate, position of any parasitized cells in the nest, and developmental stages of bees and parasites were recorded on the day of collection. Dissected nests were then inserted in transparent PVC tubing slightly larger than the diameter of the nest (ranging from ½–1 inch depending on twig diameter) for protection and to allow for easy visual observation of nest contents. This also allowed for behavioural observations of host–parasite interactions in the laboratory.

*Ceratina* species were identified using the key of Rehan and Richards (2008). Parasite identifications were made by JTH and Dr. Gary Gibson at the Canadian National Collection of Insects, Arachnids and Nematodes (CNC), Dr. Michael Gates at the National Musuem of Natural History (NMNH) in Washington, DC, as well as JV. Dr. Andrew Bennett (CNC) verified identity and nomenclature of *Hoplocryptus zoesmairi* Dalla Torre. Voucher specimens of *Baryscapus* sp. and *americana*, *Eupelmus vesicularis* (Retzius), *Coelopencyrtus* sp., *Axima zabriskiei* Howard and *Eurytoma* sp. near *apiculae*, were deposited in the CNC. *Baryscapus* sp., *Coelopencyrtus* sp., *Eupelmus vesicularis* and *Eurytoma* sp. near *apiculae* are labelled as CNC Ident. lot # 2008-341, and *Baryscapus* sp., *Axima zabriskiei* and *H. zoesmairi* as 2009-188.

### Parasite development and classification

Hosts were observed on a daily basis to detect parasitoid presence. Position in the nest, stage parasitized, and parasitoid species were recorded as soon as they became apparent. Developmental milestones such as defecation, pupation, pigmentation of the exoskeleton as well as emergence dates were recorded for parasites whenever possible.

Once parasitoids had pupated they were transferred to their own individual 0.2 mL microcentrofuge tubes prior to eclosion. Upon emergence parasitoids were placed in 70% ethanol for later identification.

**Data Analysis**

All data were analyzed using SAS 9.1. Parasite prevalence is defined as the number of individuals affected by a particular parasite species divided by the number of hosts examined (Margolis et al. 1982). Parasite frequency is defined as whether that particular species is present in the nest, regardless how many individuals in the nest were parasitized. G-tests for goodness of fit were used when sample sizes were large, Fisher's exact tests were used when expected values were small (<5). *Hoplocryptus zoesmairi* has not been included in statistics as it is a predator.

# Results

**Host parasitism**

Eight species of arthropod parasites representing two classes (Insecta, Arachnida), two orders (Hymenoptera and Trombidiformes), and seven families were reared from a total of 107 *C. dupla* and *C. calcarata* nests containing 850 brood cells. Characteristics of these eight species are compared in Table 1. Of the 107 nests collected, 64 were teasel, 36 raspberry, and 7 sumac. Twenty-nine percent (243/850) of all brood cells were parasitized, and 68% (73/107) of nests contained at least one parasite. *Ceratina calcarata* had a significantly higher proportion of cells parasitized than *C. dupla* but the proportion of nests parasitized between host species did not differ significantly (Table 2). Parasitism for each *Ceratina* species also varied by substrate, with significantly higher proportion of cells and nests parasitized in raspberry compared to teasel (Table 2). *Ceratina calcarata* was parasitized more often than *C. dupla* when nesting in raspberry (G=20.05, d.f.=1, P<0.0001), however no difference was seen between species in teasel (G=0.04, d.f.=1, n.s.) Sumac nests were not included in substrate comparisons due to small sample size. *Ceratina dupla* nesting in raspberry was the least parasitized with 15% of available cells affected (Table 2, Fig. 1). Only seven sumac nests were found, all *C. calcarata,* in which 16/33 (48%) of immatures had been parasitized (Fig. 1).

**Parasite and predator development**

The frequency and prevalence, i.e., proportion of hosts affected, of all parasites and predators in *Ceratina* nests is presented in Table 3 for affected cells and Table 4 for affected nests. Detailed observations for each species are given below.

**Predators**

***Hoplocryptus zoesmairi* (Dalla Torre) (Hymenoptera: Ichneumonidae)**

This species has previously been associated with *C. dupla* (as *Habrocryptus graenicheri* Viereck; Viereck 1904). *Hoplocryptus* Thomson has until recently been considered a junior synonym of *Aritranis* (Förster) (Yu and Horstmann 1997), but Yu et

TABLE 1. Important developmental characteristics of natural enemies of *Ceratina dupla* and *C. calcarata* in the Niagara Region. The species are all Hymenoptera except *Pyemotes* sp. which belongs to Trombidiformes.

| Parasite/Predator | Biology | Host Species | Host nesting substrate | Natural enemies per host[a] | Host stages attacked | Previous host record |
|---|---|---|---|---|---|---|
| *Hoplocryptus zoesmairi* (Ichneumonidae) | Predator | *C. dupla, C. calcarata* | Teasel, Raspberry | Predator[a] | Larvae | Reported on *C. dupla* (Viereck 1904, Graenicher 1905), new host record *C. calcarata* |
| *Baryscapus americana* (Eulophidae) | Koinobiont Endoparasitoid | *C. dupla, C. calcarata* | Teasel, Raspberry | Gregarious (>10) | Prepupae, occasionally white eyed pupae | *B. americanus* reported from *C. calcarata* (Rau 1928, Kislow 1976), new host record *C. dupla* |
| *Baryscapus* sp. (Eulophidae) | Koinobiont Endoparasitoid | *C. calcarata* | Raspberry, Sumac | Gregarious (8–14) | Prepupae, white-eyed pupae[b] | See previous host records for *Baryscapus* sp. 1 above |
| *Coelopencyrtus* sp. (Encyrtidae) | Koinobiont Endoparasitoid | *C. calcarata* | Sumac | Gregarious (>20) | Medium larvae | *C. hylaei* reported on *C. calcarata* (Daly 1967) |
| *Eupelmus vesicularis* (Eupelmidae) | Idiobiont Ectoparasitoid | *C. dupla*[c] | Teasel | Solitary | White-eyed pupae | New host record for family Apidae as 1° host |
| *Eurytoma* sp. near *apiculae* (Eurytomidae) | Idiobiont Ectoparasitoid | *C. calcarata* | Teasel | Solitary | Large larva | Reported on *Ceratina* (Bugbee 1966). New host record *C. calcarata* |
| *Axima zabriskiei* (Eurytomidae) | Idiobiont Ectoparasitoid | *C. dupla, C. calcarata* | Raspberry, Sumac | Solitary or Gregarious | Prepupae, white-eyed pupae | Reported on *C. dupla* and *C. calcarata* (Kislow 1976, Krombien 1960, Rau 1928) |
| *Pyemotes* sp. (Pyemotidae) | General Ectoparasite | *C. dupla, C. calcarata* | Teasel, Raspberry | Gregarious | All larval and pupal stages | New host record for both species |

a) Multiple Ceratina immatures are consumed in the development of one larva.
b) Parasitoids overwinter as full grown larvae.
c) May be a hyperparasitoid on *Baryscapus americana*.

TABLE 2. Prevalence of natural enemies associated with *Ceratina dupla* and *C. calcarata* in each substrate. Due to low sample sizes sumac was excluded from statistical analysis of parasitism amongst substrates.

| Species | Substrate | Prevalence (%) | |
|---|---|---|---|
| | | **Brood cells** | **Nests** |
| *C. dupla* | Teasel | 107/426 | 27/49 |
| | Raspberry | 15/97 | 9/10 |
| | **Total** | **122/523** | **36/59** |
| *C. calcarata* | Teasel | 25/96 | 8/15 |
| | Raspberry | 80/198 | 25/26 |
| | Sumac | 16/33 | 4/7 |
| | **Total** | **121/327** | **37/48** |
| **Grand Total** | | **243/850** | **73/107** |
| ***C. dupla* vs. *C. calcarata*** | **G=18.42, d.f.=1, P<0.0001** | G=3.21, d.f.=1, P=0.07 | |
| **Teasel vs. Raspberry** | **G=4.44, d.f=1, P=0.04** | **G=20.21, d.f.=1, P<0.0001** | |



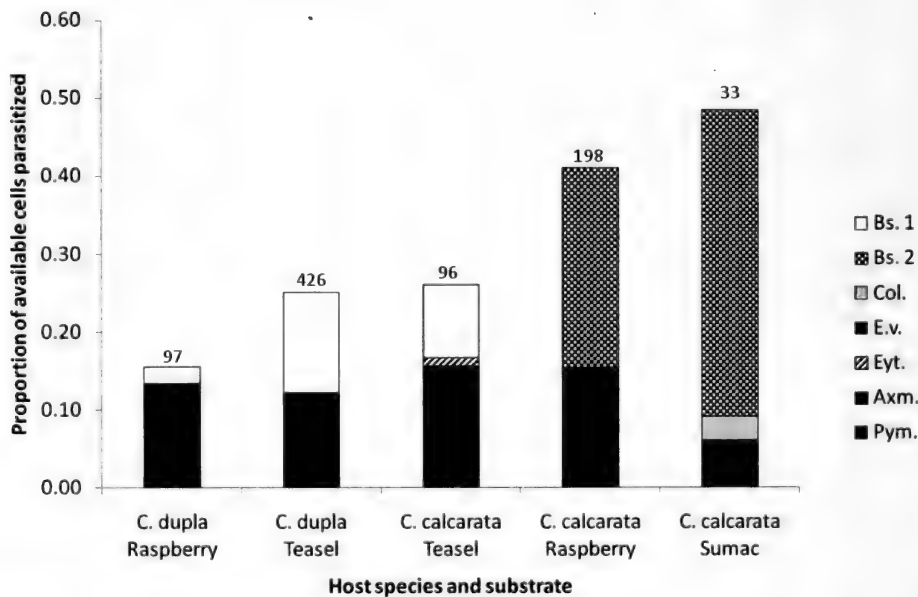FIGURE 1. The proportion of available cells parasitized for *Ceratina dupla* and *C. calcarata* in each substrate. Values associated with each bar indicate the number of available cells for each species in each substrate. Abbreviations: Bs. 1.=*Baryscapus americana*, Bs. 2=*Baryscapus* sp., Col.= *Coelopencyrtus* sp., E.v.= *Eupelmus vesicularis*, Eyt.= *Eurytoma* sp. near *apiculae*, Axm.=*Axima zabriskiei*, Pym.= *Pyemotes* sp.

TABLE 3. Prevalence of parasites on each *Ceratina* host by affected brood cells. Prevalence is the proportion of brood parasitized in each host species in each nesting substrate. Significance testing was conducted using G tests unless indicated by * where Fisher's Exact tests were used.

| Parasite | Host | Substrate | Prevalence cells available | Statistics |
|---|---|---|---|---|
| *Baryscapus americana* | *C. dupla* | Teasel | 55/426 | **Species:** |
| (Eulophidae) | | Raspberry | 2/97 | **G= 21.42, d.f.=1,** |
| | | **Total** | **57/523** | **P<0.0001** |
| | *C. calcarata* | Teasel | 9/96 | |
| | | Raspberry | 0/198 | **Substrate:** |
| | | Sumac | 0/33 | **G=46.68 ,d.f=1,** |
| | | **Total** | **9/327** | **P<0.0001** |
| *Baryscapus* sp. | *C. calcarata* | Teasel | 0/96 | |
| (Eulophidae) | | Raspberry | 51/198 | Substrate |
| | | Sumac | 13/33 | G= 2.49, d.f.=1, |
| | | **Total** | **64/327** | n.s. |
| *Coelopencyrtus* sp. | *C. calcarata* | Teasel | 0/96 | |
| (Encyrtidae) | | Raspberry | 0/198 | |
| | | Sumac | 1/33 | |
| | | **Total** | **1/327** | |
| *Eupelmus vesicularis* | *C. dupla* | Teasel | 1/426) | |
| (Eupelmidae) | | Raspberry | 0/97 | |
| | | **Total** | **1/523** | |
| *Eurytoma* sp. near *apiculae* | *C. calcarata* | Teasel | 1/96 | |
| (Eurytomidae) | | Raspberry | 0/198 | |
| | | Sumac | 0/33 | |
| | | **Total** | **1/327** | |
| *Axima zabriskiei* | *C. dupla* | Teasel | 0/426 | **Species:** |
| (Eurytomidae) | | Raspberry | 8/97 | **G= 8.02, d.f.=1,** |
| | | **Total** | **8/523** | **P=0.005** |
| | *C. calcarata* | Teasel | 0/96 | |
| | | Raspberry | 14/198 | Substrate: |
| | | Sumac | 2/33 | *$X^2$= 0.08, d.f.=1, |
| | | **Total** | **16/327** | n.s. |
| *Pyemotes* sp. | *C. dupla* | Teasel | 51/426 | |
| (Pyemotidae) | | Raspberry | 5/97 | Species: |
| | | **Total** | **56/523** | G=0.53, d.f.=1, n.s. |
| | *C. calcarata* | Teasel | 15/96 | |
| | | Raspberry | 15/198 | **Substrate:** |
| | | Sumac | 0/33 | **G= 7.56 d.f.=1,** |
| | | **Total** | **30/327** | **P=0.006** |

al. (2005) consider *Hoplocryptus* a valid genus. This is the first time this species has been recorded with *C. calcarata*.

This natural enemy is considered a predator as it always consumed multiple

TABLE 4. Infection rate of nests of *Ceratina* spp. by substrate type and species of natural enemy. Nests were scored as infected if at least one individual of the eight natural enemies were present in a nest. Significance testing was conducted using G tests unless indicated by * where Fisher's Exact tests were used.

| Natural Enemy | Host | Substrate | Nests with at least one natural enemy/ Total nests | Statistics |
|---|---|---|---|---|
| *Baryscapus americana* (Eulophidae) | *C. dupla* | Teasel | 13/49 | **Species:** |
| | | Raspberry | 2/10 | **G= 10.16, d.f.=1,** |
| | | **Total** | **15/59** | **P=0.001** |
| | *C. calcarata* | Teasel | 2/15 | |
| | | Raspberry | 0/26 | **Substrate:** |
| | | Sumac | 0/7 | **G= 6.03, d.f.=1, P=0.01** |
| | | **Total** | **2/48** | |
| *Baryscapus* sp. (Eulophidae) | *C. calcarata* | Teasel | 0/15 | |
| | | Raspberry | 16/26 | Substrate: |
| | | Sumac | 2/7 | *$X^2$= 2.45, d.f.=1, n.s. |
| | | **Total** | **18/48** | |
| *Coelopencyrtus* sp. (Encyrtidae) | *C. calcarata* | Teasel | 0/15 | |
| | | Raspberry | 0/26 | |
| | | Sumac | 1/7 | |
| | | **Total** | **1/ 48** | |
| *Eupelmus vesicularis* (Eupelmidae) | *C. dupla* | Teasel | 1/49 | |
| | | Raspberry | 0/10 | |
| | | **Total** | **1/59** | |
| *Eurytoma* sp. near *apiculae* (Eurytomidae) | *C. calcarata* | Teasel | 1/15 | |
| | | Raspberry | 0/26 | |
| | | Sumac | 0/7 | |
| | | **Total** | **1/48** | |
| *Axima zabriskiei* (Eurytomidae) | *C. dupla* | Teasel | 0/49 | |
| | | Raspberry | 4/10 | Species: |
| | | **Total** | **4/59** | G= 2.60, d.f.=1, n.s. |
| | *C. calcarata* | Teasel | 0/15 | |
| | | Raspberry | 7/26 | Substrate: |
| | | Sumac | 1/7 | *$X^2$= 0.87, d.f.=1, n.s. |
| | | **Total** | **8/48** | |
| *Pyemotes* sp. (Pyemotidae) | *C. dupla* | Teasel | 13/49 | |
| | | Raspberry | 3/10 | Species: |
| | | **Total** | **16/59** | G= 2.53, d.f.=1, n.s. |
| | *C. calcarata* | Teasel | 5/15 | |
| | | Raspberry | 2/26 | Substrate: |
| | | Sumac | 0/7 | G= 2.80, d.f.=1, n.s. |
| | | **Total** | **7/48** | |

*Ceratina* immatures before completing development. The predator egg was always laid in the innermost cell of the nest. After the egg hatched, the larva attached to the small *Ceratina* larva, but did not kill it immediately. Rather, the *H. zoesmairi* larva waited until the

*Ceratina* larva was at least half as large as its pollen mass, at which point it consumed the immature *Ceratina* and the remainder of its provisions. Once the entire contents of the cell had been consumed the larva broke down the cell septum and consumed the next larva and its pollen mass. This process was repeated, with individual *H. zoesmairi* larvae devouring anywhere from two to five *Ceratina* immatures and pollen masses, then spinning silken cocoons. Each *H. zoesmairi* larva then defecated and pupated inside its cocoon before emerging as an adult. Development from time of hatching to adulthood took 27-48 days, with emergence dates ranging from 28 July to 14 August 2008. There were four occurrences of this predator, two in *C. dupla* nests (one in teasel and one in raspberry), one in a *C. calcarata* nest (raspberry), and one in a *Ceratina* nest that contained no adult female and no surviving offspring.

## Parasitoids

### *Baryscapus americana* (Ashmead) (Hymenoptera: Eulophidae)

     *Baryscapus americana* was previously known to parasitize *C. calcarata* in Georgia (Kislow 1976) and Missouri (Rau 1928). The species was transferred from the genus *Aprostocetus* Westwood by Lasalle (1994). This is the first record of any member of the genus *Baryscapus* Förster parasitizing *C. dupla*.

     *Baryscapus americana* is a gregarious, koinobiont endoparasitoid of *Ceratina* immatures. Their presence was undetectable until they began to consume their hosts (Fig. 2a), but the larvae grew to approximately half the length of their *Ceratina* host by the time its contents had been entirely consumed. At this point the parasitoids migrated to the anterior or posterior ends of the pre-pupal skin (Fig. 2b). The parasitoids then emerged in three ways: either all individuals in the *Ceratina* larval skin pupated and emerged that summer (Fig. 2c), or all of the individuals remained as prepupae to overwinter together and emerge the following spring, or several individuals occupying a single host would pupate while the rest would overwinter. The aforementioned strategies were also observed by Kislow (1976). Of the 66 immature *Ceratina* parasitized, 20 (30%) showed total emergence, 35 (53%) overwintered as a group together, and 11 (17%) showed partial emergence, with some individuals emerging that summer and some overwintering as prepupae. Average development time was 21.6 ± 2.3 days (range 11–37) once *B. americana* larvae had begun to consume *Ceratina* immatures. Emergence was highly synchronized for non-diapausing larvae, with all newly eclosed adults emerging from the host within 24 hours.

     *Baryscapus americana* was the most common parasitoid species observed, infecting 8% (66/850) of all cells, and 16% (17/107) of all nests. This parasitoid was found in nests collected from 14 July through 1 August 2008. They were most often found parasitizing nests in teasel, with low levels of infection in raspberry, and none in sumac (Tables 3, 4). On average they infected 39% of available brood in an affected nest, ranging from one immature to the entire nest. This parasitoid predominantly affected the prepupal stage (8/9 *C. calcarata* and 53/56 *C. dupla*) and occasionally white eyed pupae. Individuals of *Baryscapus* sp. 1 were often found in nests with other associated species (7/17, 41%), including *Eurytoma* sp. near *apiculae, Axima zabriskiei, Eupelmus vesicularis* and *Pyemotes* sp.
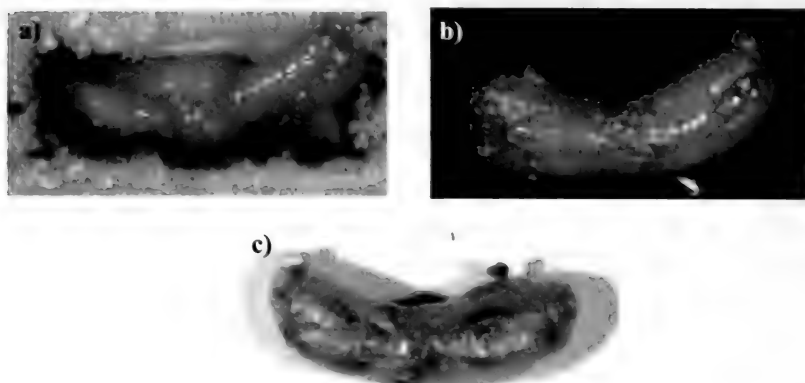
FIGURE 2. Development of *Baryscapus americana* a) Parasitoid larvae consume the contents of the *Ceratina* immature, leaving the larval skin intact. b) Full grown larvae move to the anterior and posterior ends of the host. c) Thereafter, pupation and development continue to eclosion or individuals overwinter as prepupae.

### *Baryscapus* sp. (Eulophidae)

This parasitoid which is morphologically very similar to *B. americana*, but mummifies its host, overwintered as prepupae in the larval or pupal skin of *Ceratina calcarata* only. All individuals of this gregarious, koinobiont endoparasitoid that emerged as adults were male. It infected 20% (64/327) of the total *C. calcarata* cells available and 17% (18/48) of all *C. calcarata* nests. It was found most commonly in raspberry (51 of 64 cells), occasionally in sumac (13 of 64 cells), and never in teasel. On average $3.8 \pm 0.6$ cells per affected nest were parasitized, representing 51% of infected *C. calcarata* nests on average. Other associated species were present in 8 of the 17 infected nests (47%); these were always *Pyemotes* or *Axima*. Prepupae were the most commonly affected host stage (43/64), but white-eyed pupae (21/64) were also susceptible to parasitism.

Parasitism went unnoticed until these internal parasitoids began to consume the host. Infection became evident when the larval skin of the *C. calcarata* changed dramatically in colour and consistency. The larval skin of living *Ceratina* is somewhat transparent and the gut is often visible. Parasitism caused the larval skin of the *Ceratina* to become a rusty red-brown colour; it also became much more brittle with the consistency of paper mache. The parasitoids overwintered as full grown larvae in the host, and the tough pupal casing of the larval or pupal skin may provide protection to the diapausing larvae (Legrand et al. 2004). Only males of this species emerged as adults from *Ceratina* immatures, in constrast with *Baryscapus americana* where both sexes emerged. These parasites were collected from *Ceratina* nests from 22 July through 21 August 2008.

### *Coelopencyrtus* sp. (Hymenoptera: Encyrtidae)

A single *C. calcarata* larva in a sumac nest was affected by this gregarious,

endoparasitic koinobiont. The only other observation of *C. calcarata* being attacked by *Coelopencyrtus* Timberlake is by R.W. Matthews (reported by Daly et al. 1967), who reported *C. hylaei* Burks parasitism on six consecutive cells in a nest collected in Connecticut. *Coelopencyrtus* have also been reported to parasitize members of the twig-nesting, bee genus *Hylaeus* Fabricius (Burks 1958).

The *C. calcarata* nest was collected on 7 July 2008 and parasitism became evident on 10 July 2008 when more than 20 *Coelopencyrtus* larvae could be seen consuming the bee larva, which was in the second innermost cell in a nest with six other immatures. Once the entire contents of the *Ceratina* larva had been consumed, development of the parasitoids continued inside the transparent larval skin. Eyes of the parasitoids began to darken on 4 August with their exoskeletons gaining pigmentation by 7 August. Synchronized emergence took place on 13 August, when all of the new *Coelopencyrtus* adults emerged, except for one individual that had died during development.

### *Eupelmus vesicularis* Retzius (Hymenoptera: Eupelmidae)

One *Eupelmus vesicularis* specimen was reared from a *C. dupla* nest in teasel. While this is the first host record of *E. vesicularis* parasitizing *C. dupla,* members of the genus *Eupelmus* are well known for parasitizing a large number of different hosts (Burks 1979a; Gibson 1990). *Eupelmus vesicularis* has a Holarctic distribution, but may have been introduced to North America from Europe in straw (Burks 1979a). Its first record in North America was from Pennsylvania in 1915 (Burks 1979a).

Usually a primary parasitoid, *E. vesicularis* has been occasionally reported as a secondary parasitoid (Burks 1979a). The wasp collected here had actually parasitized a white-eyed bee pupa that had also been parasitized by *Baryscapus americana*. The *E. vesicularis* egg had already been laid when the nest was collected on 15 July 2008. The parasitoid hatched and began feeding externally on the bee larva on 20 July 2008. A day later it became apparent that the bee larva had also been parasitized internally by *B. americana*. *Eupelmus vesicularis* consumed the bee larva, followed by the *B. americana* parasitoids, and pupated on 1 August. Body sclerotization was quite rapid, beginning 4 August and finishing 2 days later. The adult *E. vesicularis* emerged on 8 August 2008, 19 days after first hatching. This is the first record of the family Eupelmidae associated with a parasitoid developing in bees.

### *Eurytoma* sp. near *apiculae* Bugbee (Hymenoptera: Eurytomidae)

This is the first record of *Eurytoma* Illiger parasitizing *C. calcarata. Eurytoma apiculae* and *E. nodularis* Boheman have been reported as parasitoids on *C. callosa* Fabricius, *C. dallatoreana* Friese, *C. nanua* Cockerell, and *C. punctigena* Cockerell (Bugbee 1966; Burks 1979b; Daly 1966), and an unknown *Eurytoma* species has been observed as a parasitoid of *C. australensis* Perkins in Queensland, Australia (S. Rehan, pers. comm.).

An external parasitoid of *C. calcarata,* only one *E.* sp. near *apiculae* individual was collected which was parasitizing a larva that had almost finished eating its pollen ball in a nest constructed in teasel. The *E.* sp. near *apiculae* egg was laid in the innermost brood cell and by 16 July, 2008, had begun to feed on the host *Ceratina* larva. Over the course of the next week the parasitoid finished consuming the host, after which it defecated and then

pupated. The eyes of the *E.* sp. near *apiculae* began to darken on 27 July and the integument was fully pigmented by 1 August. The teneral adult emerged on 3 August, 2008.

### *Axima zabriskiei* Howard (Eurytomidae)

*Axima zabriskiei* has been reported as a parasitoid of both *C. dupla* and *C. calcarata* (Kislow 1976; Krombein 1960; Rau 1928). An ectoparasitic idiobiont, 1–7 *Axima* individuals could be seen consuming a single *Ceratina* immature, always a pre-pupa or white-eyed pupa, most often attached between the head and thorax and/or near the wing buds of white eyed pupae (Fig 3b). The parasitoids consumed the hosts' contents rapidly (usually in 24 – 48 hours), leaving the skin intact. It was at this point that most lab-reared parasitoids died, but two did pupate in the laboratory in 2008 (Fig. 3c). None of these chalcid parasitoids were successfully reared to adulthood in the lab in 2008 but one was reared to adulthood during 2009 collections.

*Axima zabriskiei* parasitoids infected 3% (24/850) of all available cells and 11% (12/107) of available nests. Twenty-two of the infected cells were found in raspberry (11 nests) and two cells were in sumac (one nest), for an average of $1.9 \pm 0.3$ cells per infected nest, with a maximum of four infected *Ceratina* immatures but never representing more than 50% of the total brood in a nest. *Axima zabriskiei* was found with other parasites
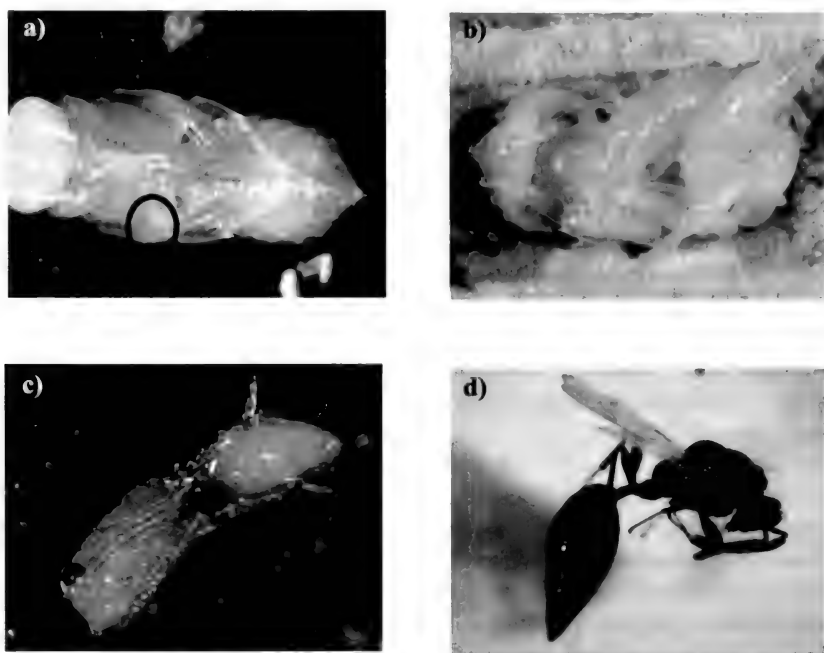


FIGURE 3. *Axima zabriskiei* wasp development. a) Newly hatched larvae pierce the soft exoskeleton of the pupa and rapidly ingest the contents (a, circle), usually within 24–48 hours. Often multiple parasitoids will attack a single *Ceratina* immature (b). Once finished feeding larvae pupate (c) before emerging as an adults (d).

in 7/12 (58%) affected nests, most often in conjunction with *Baryscapus* sp.. The first *Ceratina* nest containing *Axima zabriskiei* was collected on 14 July, with the last parasitized nest collected on 21 August 2008.

### Parasites (other than parasitoids)

### *Pyemotes* sp. (Acari: Actinedida: Pyemotidae)

*Pyemotes sp.* were the most common natural enemy found on *Ceratina* immatures, infecting 10% (86/850) of all available brood cells and 21% (23/107) of all available nests. This is the first record of *Pyemotes* mites infecting *C. dupla* and *C. calcarata,* although they have been reported on *C. dallatorreana* (Friese) in California (Daly 1966). They were more common in teasel nests (66 of 86 infected brood) than in raspberry (20 of 86 infected brood), and were not found in sumac (Table 3). On average *Pyemotes* sp. affected 3.7 ± 0.7 immatures per nest, representing 28% of the total brood in affected nests. *Pyemotes* sp. was present in nest collections from 25 June to 25 July 2008.

This external parasite was found to infect all immature stages, from small larvae to fully pigmented pupae. Multiple individuals often infected a single larva or pupa, but a single mite was effective in paralyzing and killing the host. *Pyemotes* seemed to monopolize parasitism in a nest, being found with other parasitoids only 22% of the time (5/23 nests). *Pyemotes* mites were also observed feeding on two *A. zabriskiei* larvae which subsequently died. Other members of the genus *Pyemotes* have been known to decimate nests of the bee *Melipona colimana* Ayala and the stem-nesting wasp, *Psenulus interstitalis* Cameron (Macias-Macias and Otero-Colina 2004; Matthews 2000).

## Discussion

Many parasitoids were more prevalent in one substrate than in another. *Baryscapus americana* for example, was collected significantly more often from teasel nests, with only two cells parasitized in raspberry (Table 3). While not statistically significant, *Axima zabriskiei* was collected more in raspberry than sumac (Table 3). *Pyemotes* mites did not parasitize one species more than another, but were significantly more common in teasel nests then they were in raspberry (Tables 3 and 4). While *Baryscapus* sp. was found parasitizing 64 individuals in 18 nests, it was only ever a parasite of *C. calcarata* in raspberry and sumac, never in teasel.

The parasitoid preferences seen for specific host substrates may be due to a number of factors such as the structure or biology of the host plant itself. The following discussion pertains mainly to raspberry and teasel, because so few sumac nests were collected. One possible reason for higher parasitism rates in raspberry than in teasel may be the structure of the plant species used for *Ceratina* nests. Teasel nests can only contain one nest per plant, in the straight stalk that grows perpendicular to the ground. Shrubs like raspberry (and sumac) have multiple branches in each plant and thus multiple possible nest substrates. These shrubs also tend to grow in aggregations, with multiple plants in very close proximity to one another. This can lead to higher nest densities in raspberry than in teasel. As *Ceratina dupla* and *C. calcarata* females guard only their own nests, the high density of nests in shrubs may

lead to increased rates of parasitism, as an individual parasitoid may be able to efficiently locate and infect several nests in close proximity. When comparing parasitism rates for a number of non-social hymenopteran species that nest solitarily and in aggregations, Rosenheim (1990) found that aggregated nests had higher parasitism rates in most cases.

Higher parasitism rates in raspberry may also relate to the habitat and biology of the plants in which *Ceratina* nest. Teasel is an invasive plant found in large open fields, almost always in full sunlight, while raspberry and sumac are both native plants located in shaded wood margins. In other words, *Ceratina* are nesting in different microclimates, in substrates with different biology, and with different possible chemical signatures. Numerous experiments have shown that many parasitoids are attracted to chemical cues of the flora where their host species are commonly found (Drost et al. 1986; Elzen et al. 1986; Godfray 1994; Vet 1983). If parasitoids use the microclimate and/or chemical cues emitted by the native substrates, then this might explain why the nests in native shrubs had higher parasitisation. Members of the genus *Eupelmus* parasitize a very wide range of host species (Gibson 1990). Gibson (1990) hypothesized that *Eupelmus* searched for hosts in specific microclimates, with the microclimate being of more importance than the host species. Searching for hosts by their preferred substrate may also be more effective in temperate regions due to the relatively short and synchronized phenology of foraging insects and nest substrates (Wcislo 1987).

## Acknowledgements

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# ORTHOPTERANS (ORTHOPTERA), GROUND BEETLES (COLEOPTERA: CARABIDAE), AND SPIDERS (ARANEAE) IN BURNED AND UNBURNED ALVAR WOODLANDS – THE IMPORTANCE OF POSTFIRE SUCCESSION TO INSECT DIVERSITY

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**Abstract**                          *J. ent. Soc Ont.* 141: 27-37

To contribute to understanding the importance of successional habitat to insect diversity and assist biodiversity management in globally imperilled alvar ecosystems, we surveyed three groups of arthropods in an Ottawa Valley, Ontario, alvar landscape. Using pitfall traps and sweeping, we compared grasshopper (Orthoptera), ground beetle (Coleoptera: Carabidae), and spider (Araneae) diversity in two sites on the same successional gradient: an unburned climax alvar woodland and a corresponding burned woodland that had developed into alvar shrubland nine years after fire. Between-site species similarity was 47.4% for orthopterans (9 species), 6.9% for ground beetles (2 species), and 40.9% for spiders (10 species). Both sites included regionally rare orthopterans and ground beetles. For all three groups species richness and density was higher on the burned site. The value of Brillouin's biodiversity index was higher for both orthopterans and ground beetles in the burned site but higher for spiders in the unburned alvar woodland. These results provide evidence for: (1) the importance of successional habitat to insect diversity, (2) the value of alvar shrublands to overall alvar landscape biodiversity, and (3) the potential value of fire in maintaining alvar biodiversity.

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# Introduction

Fire was a major ecological factor in much of southeastern Canada during pre-settlement times (Day 1953; Wein & MacLaren 1983), maintaining a variety of seral stages across the landscape. In the absence of fire, much of the landscape is now dominated by woodlands. Since biodiversity is considered to be higher during middle and later stages of vegetational succession in general (Bormann and Likens 1979; Brown 1984) and specifically for insects (Brown 1984; Strong et al. 1984; Kayna & Gürkan 2007), the loss of middle and late stages may be contributing to the decline in insect diversity. We chose an imperilled alvar ecosystem to investigate this hypothesis and to improve understanding of the importance of successional habitat to insect diversity. Specifically, the objective of our work was to clarify the importance of fire and subsequent succession to insect diversity through a comparative study. This involved three groups of arthropods, orthopterans (Orthoptera), ground beetles (Coleoptera: Carabidae), and spiders (Araneae) in two different habitats representing different temporal positions on the same successional gradient: an early successional alvar shrubland ("burned woodland", nine years post-fire) and a nearby climax alvar woodland ("unburned woodland").

# Materials and Methods

### The study area

The Burnt Lands, approximately 40 km SW of Ottawa in the Ottawa Valley of eastern Ontario, is one of the richest (in terms of species number and rare species) and most extensive alvar landscapes in the Great Lakes region. Alvars are globally imperilled ecosystems with a fragmented distribution in North America (Catling and Brownell 1995, 1999; Reschke et al. 1999; Brownell and Riley 2000). Evidence of past fire is common in alvars (Catling and Brownell 1998; Jones and Reschke 2005) and, considering the high plant diversity in successional alvar habitats, large scale biomass removal may significantly contribute to biodiversity protection (e.g. Catling et al. 2001, 2002; Catling and Sinclair 2002). The insect fauna of alvars is distinctive and significant (Bouchard 1997a, b, 1998; Bouchard et al. 1998, 2001, 2005), making information on the importance of alvar succession to insects particularly relevant.

The climax woodland study site included four hectares centered at 45.2569, −76.1437. The burned woodland study site, also 4 hectares in size, is centered at 45.2507, −76.1437, 0.5 km southeast of the climax site. Both sites are located in Burnt Lands Provincial Park, Lanark County, Ontario, and are part of the Burnt Lands Alvar landscape (Brunton 1986). Based on personal observations (annually 1985 to 1995) and examination of aerial photographs obtained from the National Air Photo Library of Natural Resources Canada (e.g., number A 16525-105, 29 May 1959), both of these study sites were semi-open, mixed boreal forest until 23 June 1999 when a fire burned 152 hectares, including the burned woodlands study site. The forest (Figure 1a) was dominated by *Abies balsamea* (L.) P. Mill., *Picea glauca* (Moench) Voss, *Pinus strobus* L., *Thuja occidentalis* L., and *Populus tremuloides* Michx. with an understory of mosses including *Pleurozium schreberi* (Brid.) Mitt., and *Dicranum polysetum* Sw., and occasional depauperate shrubs including

FIGURE 1. Burned (a) and unburned (b) alvar woodland on the Burnt Land Alvar west of Ottawa. a)Fallen and dead standing trees are *Abies balsamea, Picea glauca, Pinus strobus,* and *Thuja occidentalis,* regrowth on upper left is *Populus tremuloides* and *Arctostaphylos uva-ursi* can be seen flowering in the foreground.   b)The forest is dominated by *Abies balsamea, Picea glauca, Pinus banksiana, Pinus strobus, Populus tremuloides* and *Thuja occidentalis.* Shrubs of *Juniperus communis* are present in the foreground.   (a) Area burned on 23 June 1999 was taken at 45.2507, –76.1437. The right photo was taken at 45.2569, –76.1437 in late May.  Both photograps by P. M. Catling.



*Juniperus communis* L. var. *depressa* Pursh.  Nine years after the fire, the burned area had developed into a species-rich, open grassy shrubland dominated by graminoid plants such as *Danthonia spicata* (L.) Beauv. ex Roemer & J. A. Schultes  and *Carex richardsonii* R. Br., herbs such as *Packera (Senecio) paupercula* (Michx.) A. & D. Löve, and *Solidago nemoralis* Ait. var. *nemoralis,* and shrubs such as *Amelanchier alnifolia* (Nutt.) Nutt. ex M. Roemer var. *compacta* (Nielsen) McKay and *Prunus virginiana* L.  Additional information on the vegetation of the two study sites is in Catling (in press).

The Burnt Lands area is subject to fire because of its shallow soils and location on an elevated plateau of porous limestone rock.  It was named by settlers in 1870 following an extensive fire.  Additional background information on the Burnt Lands Alvar is in White (1979), Brunton (1986), and Catling et al. (2001, 2002).

## Collection and identification of insects

(1) Traps: Ten pitfall traps (15 cm x 10 cm x 5 cm deep) were buried 10 m apart in east–west transects in each of the burned and unburned alvar woodlands.  The traps were buried so that the tops were flush with the ground surface and there were no nearby obstructions.  Each trap was filled with antifreeze and a drop of soap to half depth.  Five days

after setting, the traps were checked. The survey continued from spring through summer to fall with several gaps. The dates of checking the traps were 16 May; 1, 9 June; 1, 5, 12 July; 16, 21, 26 August; and 8, 13 September 2008. These traps, set out and checked by PMC and BK, provided the entire basis for a comparison of Coleoptera and Araneae and most of the information on Orthoptera.

(2) Sweeping: To additionally sample Orthoptera, at each site on each visit, 15 minutes was spent sweeping vegetation less than 1.5 m tall. Sweeping was always done on vegetation selected randomly along the same 100 m transect.

Orthopterans were identified by PMC using Vickery and Kevan (1985). Ground beetles were identified by HG (1961, 1963, 1966, 1968, 1969a, 1969b), Bousquet and Larochelle (1993), and Goulet & Bousquet (2004). Spiders were identified by RB using primary taxonomic literature and available regional keys (e.g., Dondale and Redner 1978, 1982, 1990; Paquin and Dupérré 2003; Platnick and Dondale 1992). Ninety-one juvenile spiders and 52 juvenile orthopterans, unidentifiable to species, were excluded from the analysis. Voucher specimens were deposited in the Canadian National Collection of Insects at Agriculture and Agri-Food Canada (CNCI) in Ottawa.

## Comparing biodiversity

Biodiversity was compared with respect to: (1) total number of species and numbers of individuals within species, (2) the presence of regionally rare species (confined to alvars or known from less than four locations in the Ottawa valley), (3) the extent of distinctive composition, and (4) by applying Brillouin's Index which includes consideration of heterogeneity (species richness and evenness), is relatively sensitive to the abundance of rare species, and assumes a finite sample and collection of that sample without replacement of individuals (Krebs 1999, 2008). Replacement in this case is expected to have been the same in both habitats, would not likely have been from substantial distances (i.e., over 100 m) for these ground dwelling species, and would not have involved second generations since most of these species have a single generation in a year.

# Results

Overall, 19 species of orthopterans, 29 species of ground beetles, and 42 species of spiders were recorded (Tables 1–3). Species composition differed between the burned and unburned sites. The sites shared 9, 2, and 10 grasshopper, ground beetle, and spider species, respectively (Tables 1–3), or 47.4 %, 6.9 %, and 40.9 % of all collected grasshopper, ground beetle, and spider species. For species in common, the number of individuals was generally highest in the burned woodland for orthopterans and ground beetles but not for spiders. At each site certain unique species were common, e.g., the grasshopper *Tetrix ornata* (Say), the spider *Schizocosa avida* Walckenaer in the burned site, and the ground beetle *Synuchus impunctatus* (Say) in the unburned site.

Four regionally rare grasshopper species were present at each site (Table 1). Of these, *Melanoplus keeleri luridus* (Dodge), *Spharagemon bolli bolli* Scudder, and *Encoptolophus sordidus* (Burmeister) were found only in the burned site and *Melanoplus*

TABLE 1. Species and number of individuals of orthopterans (Orthoptera) recorded in burned and unburned woodland on the Burnt Lands. Species marked with an asterisk (*) are regionally rare.

| Species | Burned | Unburned |
|---|---|---|
| **Acrididae** | | |
| *Chloealtis conspersa* Harris* | - | 5 |
| *Chortophaga viridifasciata* (De Geer) | 13 | - |
| *Encoptolophus sordidus* (Burmeister)* | 5 | - |
| *Melanoplus bivitattus* (Say) | 3 | 1 |
| *M. dawsoni* (Scudder)* | - | 8 |
| *M. fasciatus* (F. Walker)* | 1 | 1 |
| *M. keeleri luridus* (Dodge)* | 33 | - |
| *M. punctulatus* (Scudder)* | - | 1 |
| *M. sanguinipes* (Fabricius) | 3 | - |
| *Spharagemon bolli bolli* Scudder* | 16 | - |
| **Gryllidae** | | |
| *Allonemobius fasciatus* (De Geer) | 19 | 2 |
| *Gryllus pennsylvanicus* Burmeister | 32 | 8 |
| *G. veletis* (Alexander & Bigelow) | 22 | 6 |
| **Oecanthidae** | | |
| *Oecanthus quadripunctatus* (Beutenmüller) | 3 | 2 |
| **Phaneropteridae** | | |
| *Scudderia curvicauda* (De Geer) | 1 | 1 |
| *S. furcata furcata* Brunner von Wattenwyl | 1 | 1 |
| **Rhaphidophoridae** | | |
| *Ceuthophilus cf. maculata* (Harris) | - | 7 |
| **Tetrigidae** | | |
| *Nomotettix cristatus cristatus* (Scudder) | 3 | 1 |
| *Tetrix ornata ornata* (Say) | 23 | - |
| **Totals** | **178** | **44** |

*dawsoni* (Scudder), *M. punctulatus* (Scudder), and *Chloealtis conspersa* Harris only in the unburned site. Similarly, of the 6 regionally rare ground beetle species collected during the study, *Harpalus indigens* Casey, *Selenophorus gagatinus* Dejean, *S. opalinus* (LeConte), and the southern *Calathus opaculus* LeConte were found only in the burned woodland, while the boreal species *Harpalus fulvilabris* Mannerheim and the alvar-restricted species *Pterostichus novus* Straneo were found only in the unburned woodland. All collected spiders were members of wide-ranging and relatively common species.

Species richness was greater in the burned woodland for all three groups. With respect to orthopterans, the burned woodland had 15 species and unburned woodland had 13 species (Table 1, Figure 2). For spiders, the difference was greater with 31 species in the burned compared to 22 species in the unburned site (Table 3, Figure 2). Ground beetles provided the greatest contrast in species richness, with 21 species in the burned area compared to 9 species in the unburned area (Table 2, Figure 2).

In all three groups there were more individuals in the burned area (Table 3). This was most pronounced in the case of orthopterans with 3.55 times as many in the burned woodland, and least for spiders with 1.69 times as many in the burned woodland.

TABLE 2. Number of various species of ground beetles (Coleoptera: Carabidae) in 10 pitfall traps in each of a burned and unburned alvar woodland. Species marked with an asterisk (*) are regionally rare.

| Species | Burned | Unburned |
|---|---|---|
| *Agonum cupripenne* (Say) | 2 | - |
| *Amara pennsylvanica* Hayward | 2 | - |
| *Anisodactylus rusticus* (Say) | 5 | - |
| *Calathus gregarius* (Say) | 2 | 6 |
| *C. opaculus* LeConte* | 1 | - |
| *Calosoma calidum* Fabricius | 2 | - |
| *Carabus nemoralis* O.F. Müller | 35 | 8 |
| *Chlaenius emarginatus* Say | 1 | - |
| *Cicindela punctulata* Olivier | 5 | - |
| *C. purpurea* Olivier | 1 | - |
| *C. sexguttata* Fabricius | 3 | - |
| *Diplocheila obtusa* (LeConte) | 1 | - |
| *Harpalus faunus* Say | 34 | - |
| *H. fulvilabris* Mannerheim* | - | 1 |
| *H. indigens* Casey* | 3 | - |
| *H. laevipes* Zetterstedt | 1 | - |
| *H. laticeps* LeConte ˙ | 10 | - |
| *H. opacipennis* (Haldeman) | 1 | - |
| *H. pensylvanicus* (De Geer) | 9 | - |
| *Notiophilus aeneus* (Herbst) | - | 1 |
| *Poecilus lucublandus* (Say) | - | 8 |
| *Pterostichus novus* Straneo* | - | 1 |
| *P. mutus* (Say) | 1 | - |
| *P. pensylvanicus* LeConte | - | 5 |
| *Selenophorus gagatinus* Dejean* | 4 | - |
| *S. opalinus* (LeConte)* | 1 | - |
| *Sphaeroderus stenostomus lecontei* Dejean | - | 2 |
| *Synuchus impunctatus* (Say) | - | 34 |
| **Totals** | **124** | **66** |

The value of Brillouin's biodiversity index was higher for both orthopterans and ground beetles in the burned site but higher for spiders in the unburned woodland (Figure 2).

## Discussion

In some cases the much greater presence of a species in either habitat is to be expected on the basis of known ecological associations of a general or specific nature. For example, the orthopterans found only in woodland (*Chloealtis conspersa* and *Melanoplus punctulatus*) are known to require wood for oviposition, and the latter species is found mostly on tree trunks (Vickery and Kevan 1985). The ground beetles present are mostly normal to one site or the other (Lindroth 1961). The large number of *Carabus nemoralis* in the open areas may be a result of greater abundance of earthworms in the more mineral substrates of the open area as compared to the more acidic needle litter of the woodland. *Harpalus faunus*, which collects small seeds, may be more abundant in the burned area as a

TABLE 3. Numbers of various species of spiders (Araneae) in 10 pitfall traps in each of a burned and unburned alvar woodland.

| Species | Burned | Unburned |
|---|---|---|
| **Agelenidae** | | |
| *Agelenopsis potteri* (Blackwall) | 7 | 6 |
| *Agelenopsis utahana* (Chamberlin & Ivie) | 1 | - |
| **Clubionidae** | | |
| *Clubiona mixta* Emerton | 1 | - |
| *Elaver excepta* (L. Koch) | - | 2 |
| **Corinnidae** | | |
| *Castianeira longipalpa* (Hentz) | 3 | - |
| **Gnaphosidae** | | |
| *Callilepis pluto* Banks | 1 | - |
| *Drassodes neglectus* (Keyserling) | 13 | - |
| *Drassylus depressus* (Emerton) | 1 | - |
| *D. niger* (Banks) | - | 1 |
| *D. socius* Chamberlin | - | 2 |
| *Haplodrassus bicornis* (Emerton) | - | 2 |
| *H. signifer* (C.L. Koch) | 8 | - |
| *Herpyllus ecclesiasticus* Hentz | - | 1 |
| *Gnaphosa muscorum* (L. Koch) | 24 | 5 |
| *Micaria laticeps* Emerton | 1 | - |
| *Z. fratris* Chamberlin | 2 | 11 |
| *Z. hentzi* Barrows | 7 | 17 |
| **Hahniidae** | | |
| *Neoantistea magna* (Keyserling) | - | 5 |
| **Liocranidae** | | |
| *Agroeca ornata* Banks | - | 4 |
| *A. pratensis* Emerton | 1 | 6 |
| **Lycosidae** | | |
| *Alopecosa aculeata* (Clerck) | 2 | 10 |
| *Hogna frondicola* (Emerton) | - | 11 |
| *P. distincta* (Blackwall) | 9 | 16 |
| *P. moesta* Banks | - | 1 |
| *Schizocosa avida* (Walckenaer) | 76 | - |
| *S. crassipalpata* Roewer | 10 | - |
| *S. saltatrix* (Hentz) | 14 | 6 |
| *Trochosa ruricola* (De Geer) | 3 | - |
| *T. terricola* Thorell | 3 | 23 |
| **Oxyopidae** | | |
| *Oxyopes scalaris* Hentz | - | 1 |
| **Philodromidae** | | |
| *Thanatus formicinus* (Clerck) | 2 | 1 |
| **Salticidae** | | |
| *Evarcha hoyi* (Peckham & Peckham) | - | 1 |
| *Habronattus viridipes* (Hentz) | 8 | - |
| *Phidippus purpuratus* Keyserling | 2 | - |
| **Thomisidae** | | |
| *Xysticus alboniger* Turnbull et al. | 5 | - |
| *X. ampullatus* Turnbull et al. | 9 | - |
| *X. canadensis* Gertsch | 2 | - |
| *X. elegans* Keyserling | 3 | 8 |
| *X. luctuosus* (Blackwall) | 1 | - |
| *X. pellax* O. P.-Cambridge | 15 | - |
| *X. punctatus* Keyserling | 1 | - |
| *X. triguttatus* Keyserling | 2 | - |
| **Totals** | **237** | **140** |
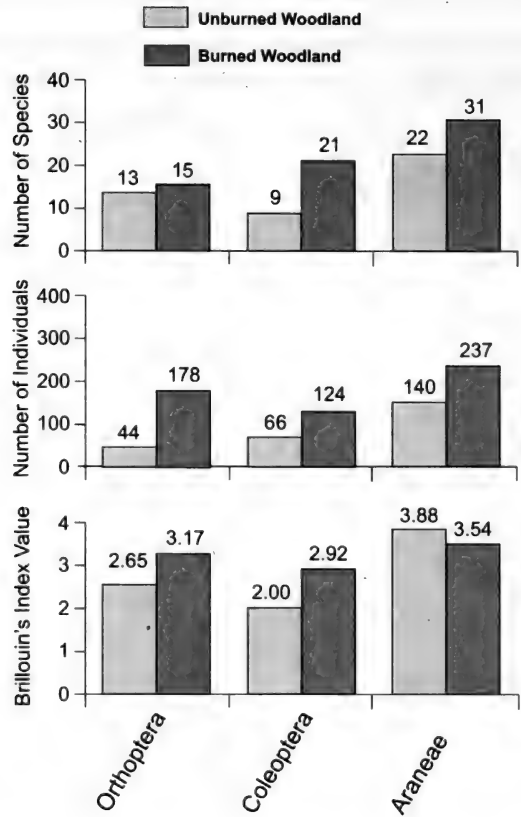
FIGURE 2. Number of species, number of individuals, and the value of Brillouin's Index for three arthropod groups in burned and unburned alvar woodland.

result of greater numbers of herbs with small seeds in that area. The abundance of *Synuchus impunctatus* in the unburned woodland and its absence from the burned area is anticipated on the basis of its association with deep litter (Lindroth 1961), which was removed by fire from the burn. Likewise with respect to the spiders, some of the major differences were anticipated based on known species and habitat associations, such as the relationship of many *Schizocosa* and *Xysticus* species with dry, open habitats.

Our results suggest that the relatively long lasting successional shrubland that follows burning of alvar woodland differs from the original woodland in species composition, higher species richness and density, and higher biodiversity index values for some arthropod groups. The fact that the Brilluoin Index has a slightly lower value for spiders in the burned area than in the unburned is a consequence of less evenness in the number of individuals of different species in that site, despite higher diversity and species number. Other studies similarly found highest insect diversity in middle successional stages (e.g., Brown 1984; Kayna & Gürkan 2007) and qualitative differences between burned and unburned sites (e.g., Burger et al. 2005). The importance of succession and differing species compositions in different seral stages is not surprising considering that opposite ends of the sere are characterized by organisms with different life history strategies (Brown 1984).

The tendency for insect diversity to track plant diversity (e.g. Knops et al. 1999) may help to explain the generally higher insect diversity in the burned woodland, which had higher vascular plant diversity than the unburned alvar woodland (Catling in press). With regard to herbivorous insect diversity, which is tracked by predator and parasite diversity (e.g., Knops et al. 1999), other explanatory factors associated with high plant diversity may include increased insect richness per plant host and higher average plant host specificity (Lewinsohn et al. 2005), as well as increased structural diversity of plant hosts (Southwood et al. 1979).

The evidence presented here for the importance of succession to ground-dwelling insects on alvars is based on a single location and a rather limited sampling procedure. However, the relationship seems to hold for other alvar sites in the Ottawa valley based on general comparative surveys (Catling, unpublished data). Although management of alvar vegetation with succession-initiating fire seems appropriate, it may also have negative impacts (Siemann et al. 1996), especially if it does not allow survival of some species in unburned patches that serve as refugia. Fire or any form of biomass removal should be part of a broad, long-term landscape management plan that takes many species and species groups into account.

## Acknowledgements

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# THE BUMBLE BEES OF SOUTHERN ONTARIO: NOTES ON NATURAL HISTORY AND DISTRIBUTION

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**Abstract**                                             *J. ent. Soc. Ont.* 141: 39-68

Although North American bumble bees are common and easily recognizable insects in many habitats, details of their natural history are poorly known. This study presents basic ecological information based on a literature review, databased insect collections and recent survey work performed throughout southern Ontario.   As a result of this review, phenology, food plants, distribution and habitat associations are summarized for each species of this important group of pollinators.

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## Introduction

The plight of native pollinators has recently gained the interest of scientists and naturalists alike.  Globally, bees have been documented as declining throughout their native ranges (Berenbaum et al. 2007; Biesmeijer et al. 2006).  Conservation plans are highly dependent upon basic natural information, which is lacking for almost all North American bee species.  Southern Ontario is an important region to consider as it has relatively high biodiversity and many potential threats to these native organisms (Allen et al. 1990).  Habitat loss and fragmentation due to high population density and agricultural production are major threats to wild pollinators in this region (eg. Taki et al. 2007; Findlay and Houlahan 1997). Understanding basic natural history aspects of native bees in southern Ontario is important to conserve these pollinators and their associated native flowering plants.

Bumble bees are eusocial organisms with an annual colony cycle.  Queens emerge in the spring, find nest sites, build honey pots and lay eggs.  Hatched workers then take over foraging and nest tending duties, while the queen focuses on reproduction.  Towards the end of the colony cycle, males and new queens are produced.  These reproductive individuals leave the nest and mate.  Newly mated queens overwinter in rotting logs, mulch or dirt while the rest of the colony perishes with the onset of cold weather.  Cuckoo bumble bees (subgenus *Psithyrus*) are exceptions, as they do not produce a worker caste, but usurp the colonies of other species and the host workers collect resources for the cuckoo's offspring

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instead. The timing of queen emergence, worker production and colony decline for each species varies with latitude, elevation and weather variation from year to year (Benton 2006). Here, using historical and recent records of bumble bees in southern Ontario, information is provided on distribution, phenology, habitat and forage for each of the 18 species found in this region.

## Materials and Methods

Phenology graphs were produced using bumble bee records from collections and recent surveys. Bumble bee specimens from southern Ontario insect collections (University of Guelph, Royal Ontario Museum, Canadian Museum of Nature, PCYU York University, Algonquin Provincial Park) were databased with species identifications being determined or verified by SR Colla. Surveys were made throughout southern Ontario during the summers of 2005-2009 (Colla and Packer 2008; Colla et al. 2006; Colla, unpublished). Bees were collected using hand nets and were either identified and released or collected for identification. Plant records were accumulated from specimen labels, surveys, the literature (Macfarlane 1974; Robertson 1929). In Robertson (1929), plant records were not determined in southern Ontario but were included if the taxon occurs naturally in the region. Habitat notes were collected from Macfarlane (1974) and field surveys.

## Results

A total of 9052 bumble bee records representing 18 species spanning the years 1876-2009 were accumulated from insect collections (n=6506) and field surveys (n=2546). Laverty and Harder (1988) note the presence of *B. frigidus* Smith in southern Ontario, but specimens for this species were not found during this study. Ecological information is presented below for each species. Introduced plant species are marked with an asterisk (*). Figures presenting the phenology and collection locations for each species are presented at the end of the paper.

### *Bombus impatiens* Cresson: the common eastern bumble bee
**Phenology and Distribution:** This species exhibits early spring emergence (earliest record April 23) with a long colony cycle extending into autumn and has a widespread distribution (Fig. 1).
**Floral Records:** Robertson (1929): *Actinomeris, Agastache, Amphicarpaea, Arabis, Asclepias, Blephilia, Camassia, Campanula, Caulophyllum, Cercis, Cicuta, Claytonia, Clematis, Collinsia, Coreopsis, Crataegus, Delphinium, Dentaria, Desmodium, Dasistoma, Dicentra, Fragaria, Gaura, Geranium, Gerardia, Gleditzia, Gymnocladus, Helenium, Helianthus, Helianthus divaricatus, Heliopsis, Hydrophyllum, Impatiens, Lactuca, Liatris, Lithospermum, Lobelia, Lonicera, Lycopus, Lythrum, Monarda, Nelumbo, Osmorhiza, Penstemon, Petalostemum, Phlox, Podophyllum, Polemonium, Prenanthes, Prunella, Prunus, Pycnanthemum, Pyrus, Ribes, Rudbeckia, Salix,*

*Scrophularia, Scutellaria, Sicyos, Silphium, Sium, Smilax, Stachys, Staphylea, Symphoricarpos, Symphyotrichum, Teucrium, Tradescantia, Verbena, Viola, Zizia.*
Macfarlane (1974): *Acer ginnala\*, Aesculus hippocataneum\*, Althaea rosea\*, Antirrhinum majus\*, Arctium minus\*, Berberis thunbergii\*, Caragana arborescens\*, Carduus nutans\*, Cotoneaster adpressa\*, Daucus carota\*, Dipsacus sylvestris\*, Echium vulgare\*, Epilodium angustifolium, Euthamia graminifolia, Helianthus annuus\*, Hesperis matronalis\*, Hydrophyllum virginianum, Hypericum perforatum\*, Impatiens capensis, Kalmia latifolia, Kolkwitzia amabilis\*, Ligustrum vulgare\*, Lonicera caerulea, Lonicera periclymenum\*, Lonicera tatarica\*, Medicago sativa\*, Melilotus alba\*, Nepeta cataria\*, Oenthera biennis, Phaseolus coccineus\*, Philadelphus coronarius\*, Potentilla, Prunus cerasus\*, Prunus tomentosa\*, Pyrus malus\*, Rhododendron, Ribes grossularia\*, Ribes nigrum\*, Ribes rubrum\*, Robinia fertilis\*, Rubus, Salix, Salvia sylvestris\*, Silene vulgaris\*, Solanum dulcamara\*, Solidago canadensis, Solidago flexicaulis, Solidago rugosa, Stachys palustris\*, Symphyotrichum (Aster) ericoides, Symphyotrichum (Aster) lateriflorum, Symphyotrichum novae-angliae, Symphytum officinale\*, Syringa vulgaris\*, Taraxacum officinale\*, Tilia platyphyllos\*, Trifolium pratense\*, Trifolium repens\*, Vicia cracca\*, Weigelia florida\*.*
Field and Museum Records: *Amelanchier alnifolia, Ceanothus americanus, Centaurea macrocephala, Cephalanthus, Cephalanthus occidentalis, Chelone glabra, Clinopodium vulgare, Echinacea, Erythronium, Eupatorium fistulosum, Eupatorium maculatum, Justicia, Lespedeza intermedia, Linum, Lupinus, Mentha, Onopordum acanthium\*, Pediomelum, Pontederia cordata, Prunus virginiana, Rhexia virginica, Rhus, Rubus idaeus, Rubus occidentalis, Rudbeckia hirta, Solidago altissima, Solidago bicolor, Solidago caesia, Solidago sempervirens, Spiraea, Spiraea alba, Uvularia, Vaccinium angustifolium, Vaccinium vacillans.*
**Habitats:** Close to or within wooded areas, open fields, urban parks and gardens, wetlands.

### *Bombus bimaculatus* Cresson: the two-spotted bumble bee
**Phenology and Distribution:** This species exhibits early spring emergence (earliest record April 13) and has a widespread distribution (Fig. 2).
**Floral Records:** Robertson (1929): *Amelanchier, Blephilia, Collinsia, Cephalanthus, Dentaria, Dicentra, Geranium, Helianthus, Hydrophyllum, Mertensia, Monarda, Phlox, Polemonium, Ribes, Triosteum, Uvularia, Verbena.*
Macfarlane (1974): *Ajuga genevensis\*, Ajuga reptans\*, Aesculus hippocataneum\*, Camassia scilloides, Carduus nutans\*, Cotoneaster adpressa\*, Cynoglossum officinale\*, Deutzia gracilis\*, Dipsacus sylvestris\*, Echium vulgare\*, Hydrophyllum virginianum, Hypericum perforatum\*, Lamium amplexicaule\*, Leonurus cardiaca\*, Linaria vulgaris\*, Lonicera caerulea, Lonicera periclymenum\*, Lonicera tatarica\*, Mahonia aquifolium, Melilotus alba\*, Medicago sativa\*, Monarda didyma, Onopordum acanthium\*, Prunella vulgaris\*, Prunus tomentosa\*, Pyrus malus\*, Ribes grossularia\*, Ribes nigrum\*, Robinia fertilis\*, Salix, Solanum dulcamara\*, Solidago canadensis, Solidago flexicaulis, Solidago graminifolia, Symphytum officinale\*, Syringa vulgaris\*, Taraxacum officinale\*, Trifolium pratense\*, Trifolium repens\*, Vicia cracca\*, Weigelia florida\*.*
Field and Museum Records: *Arabis, Asclepias, Campanula, Campanula rotundifolia, Caulophyllum, Ceanothus americanus, Centaurea macrocephala, Cephalanthus occidentalis,*

*Claytonia, Clinopodium vulgare, Dasistoma, Desmodium, Dicentra cucullaria, Echinacea, Erythronium albidum, Euthamia graminifolia, Gaylussacia, Hypericum prolificum, Kalmia polifolia, Lonicera, Lotus corniculatus\*, Lupinus, Lythrum alatum, Mentha, Pontederia cordata, Rhexia virginica, Rhus glabra, Rubus odoratus, Spiraea, Spiraea alba, Tilia americana, Vaccinium angustifolium, Vaccinium corymbosum, Vaccinium myrtilloides, Vaccinium vacillans, Viola.*

**Habitats:** Close to or within wooded areas, urban parks and gardens.

### *Bombus terricola* Kirby: the yellow-banded bumble bee

**Phenology and Distribution:** This species exhibits early spring emergence (earliest record April 24) and has historically a widespread distribution (except extreme southwestern Ontario) with fewer recent records (Fig. 3).

**Floral Records:** Macfarlane (1974): *Berberis thunbergii\*, Caragana arborescens\*, Carduus nutans\*, Centaurea jacea\*, Cirsium arvense\*, Cotoneaster adpressa\*, Echium vulgare\*, Hydrophyllum virginianum, Hypericum perforatum\*, Impatiens capensis, Lactuca canadensis, Lonicera caerulea, Lonicera tatarica\*, Melilotus alba\*, Medicago sativa\*, Philadelphus coronarius\*, Prunus cerasus\*, Prunus tomentosa\*, Pyrus malus\*, Rhus typhina, Ribes grossularia\*, Ribes nigrum\*, Robinia fertilis\*, Salix, Solanum dulcamara\*, Solidago canadensis, Solidago flexicaulis, Solidago hispida, Solidago juncea, Sonchus oleraceus\*, Sorbus americana, Spiraea, Symphyotrichum (Aster) ericoides, Symphyotrichum (Aster) lateriflorum, Symphyotrichum novae-anglia, Symphytum officinale\*, Syringa vulgaris\*, Taraxacum officinale\*, Tilia platyphyllos\*, Trifolium pratense\*, Trifolium repens\*, Vicia cracca\*, Weigelia florida\*.*

Field and Museum Records: *Anaphalis margaritacea, Aquilegia canadensis, Aralia, Arctostaphylos uva-ursi, Asclepias, Asclepias incarnata, Asclepias syriaca, Astragalus, Baptisia tinctoria, Diervilla lonicera, Epigaea repens, Erigeron philadelphicus, Epilodium angustifolium, Eupatorium fistulosum, Eupatorium maculatum, Eurybia macrophylla, Euthamia graminifolia, Gaylussacia, Heracleum lanatum, Kalmia, Kalmia augustifolia, Ledum groenlandicum, Linaria vulgaris\*, Lupinus, Mertensia, Monarda fistulosa, Onopordum acanthium\*, Pontederia cordata, Prunus, Prunus pensylvanica, Rhexia virginica, Rhus, Senecio, Solidago, Spiraea latifolia, Thalictrum pubescens, Tilia americana, Trifolium hybridum\*, Urticularia cornuta, Vaccinium angustifolium, Vaccinium corymbosum.*

**Habitats:** Close to or within wooded areas.

### *Bombus vagans* Smith: the half-black bumble bee

**Phenology and Distribution:** This species exhibits early spring emergence (earliest record April 21) with a long colony cycle extending into the fall and has a widespread distribution (Fig. 4).

**Floral Records:** Robertson (1929): *Blephilia, Cercis, Claytonia, Clematis, Delphinium, Dicentra, Ellisia, Erigenia, Geranium, Hydrophyllum, Hypericum, Ipomoea, Liatris, Lobelia, Mertensia, Mimulus, Monarda, Phlox, Physostegia, Polygonatum, Polemonium, Prunella, Ribes, Scrophularia, Scutellaria, Stachys, Staphylea, Symphoricarpos, Teucrium, Tradescantia, Triosteum, Verbascum, Verbena, Veronica, Viola, Zizia.*

Macfarlane (1974): *Aesculus hippocataneum\*, Althaea rosea\*, Arctium minus\*, Berberis*

*thunbergii\**, *Carduus nutans\**, *Centaurea jacea\**, *Cichorium intybus\**, *Cirsium arvense\**, *Crataegus*, *Dipsacus sylvestris\**, *Daucus carota\**, *Echium vulgare\**, *Erica cinerea\**, *Helianthus annuus\**, *Hesperis matronalis\**, *Hydrophyllum virginianum*, *Hypericum perforatum\**, *Impatiens capensis*, *Kolkwitzia amabilis\**, *Leonurus cardiaca\**, *Linaria vulgaris\**, *Lonicera periclymenum\**, *Lonicera tatarica\**, *Lotus corniculatus\**, *Melilotus alba\**, *Medicago sativa\**, *Nepeta cataria\**, *Onobrychis viciifolia\**, *Prunella vulgaris\**, *Prunus cerasus\**, *Pyrus malus\**, *Ribes nigrum\**, *Rubus*, *Silene vulgaris\**, *Solanum dulcamara\**, *Sonchus oleraceus\**, *Symphyotrichum (Aster) lateriflorum*, *Symphyotrichum novae-angliae*, *Symphytum officinale\**, *Syringa vulgaris\**, *Tamarix gallica\**, *Taraxacum officinale\**, *Trifolium pratense\**, *Trifolium repens\**, *Verbena hastata*, *Vicia cracca\**, *Weigelia florida\**.

Field and Museum Records: *Amphicarpaea*, *Anaphalis margaritacea*, *Apocynum*, *Aquilegia canadensis*, *Aralia*, *Aralia hispida*, *Asclepias incarnata*, *Asclepias syriaca*, *Astragalus canadensis*, *Chelone glabra*, *Clinopodium vulgare*, *Collinsonia canadensis*, *Cornus*, *Dasistoma*, *Decodon*, *Desmodium*, *Diervilla lonicera*, *Erythronium albidum*, *Eupatorium fistulosum*, *Eupatorium maculatum*, *Eurybia macrophylla*, *Euthamia graminifolia*, *Gerardia pedicularia*, *Hypericum prolificum*, *Lactuca canadensis*, *Ledum groenlandicum*, *Lonicera*, *Lupinus*, *Mentha*, *Monarda fistulosa*, *Nymphaea odorata*, *Onopordum acanthium\**, *Pontederia cordata*, *Prunus*, *Pyrus*, *Rhexia virginica*, *Rhododendron*, *Rubus idaeus*, *Rubus odoratus*, *Sarracenia purpurea*, *Scutellaria lateriflora*, *Solidago altissima*, *Solidago canadensis*, *Solidago flexicaulis*, *Solidago hispida*, *Solidago juncea*, *Solidago sempervirens*, *Spiraea alba*, *Tilia americana*, *Vaccinium angustifolium*.

**Habitats**: Close to or within wooded areas, urban parks and gardens.

### *Bombus perplexus* Cresson: the confusing bumble bee
**Phenology and Distribution:** This species exhibits early spring emergence (earliest record April 16) and has a widespread distribution (Fig. 5).
**Floral Records:** Macfarlane (1974): *Althaea rosea\**, *Asclepias incarnata*, *Asclepias syriaca*, *Berberis thunbergii\**, *Campanula rapunculoides\**, *Carduus nutans\**, *Cirsium arvense\**, *Cotoneaster adpressa\**, *Dipsacus sylvestris\**, *Echium vulgare\**, *Helianthus annuus\**, *Hesperis matronalis\**, *Hydrophyllum virginianum*, *Lonicera caerulea*, *Lonicera tatarica\**, *Onopordum acanthium\**, *Philadelphus coronarius\**, *Prunus americana*, *Prunus cerasus\**, *Pyrus malus\**, *Ribes grossularia\**, *Ribes nigrum\**, *Robinia fertilis\**, *Salix*, *Solidago*, *Solidago altissima*, *Solidago canadensis*, *Solidago flexicaulis*, *Symphytum officinale\**, *Taraxacum officinale\**, *Tilia americana*, *Tilia platyphyllos\**, *Trifolium pratense\**, *Weigelia florida\**.

Field and Museum Records: *Aralia*, *Arctostaphylos uva-ursi*, *Astragalus canadensis*, *Campanula rotundifolia*, *Cephalanthus*, *Collinsonia canadensis*, *Desmodium*, *Echinacea*, *Erythronium albidum*, *Eupatorium*, *Eupatorium fistulosum*, *Eupatorium maculatum*, *Euthamia graminifolia*, *Fragaria*, *Helianthus*, *Hypericum perforatum\**, *Hypericum prolificum*, *Kalmia latifolia*, *Lonicera*, *Lotus corniculatus\**, *Lysimachia ciliata*, *Medicago sativa\**, *Mentha*, *Monarda*, *Nymphaea odorata*, *Penstemon*, *Pontederia cordata*, *Prunus*, *Rhexia virginica*, *Rubus odoratus*, *Rudbeckia hirta*, *Spiranthes lacera*, *Spiranthes romanzoffiana*, *Spiraea*, *Spiraea alba*, *Spiraea latifolia*, *Symphyotrichum*, *Syringa vulgaris\**, *Tamarix gallica\**, *Vaccinium angustifolium*, *Vaccinium corymbosum*, *Vaccinium*

*myrtilloides, Vaccinium vacillans, Viola.*
**Habitats:** Close to or within wooded areas, urban parks and gardens, wetlands.

## *Bombus griseocollis* DeGeer: the brown-belted bumble bee
**Phenology and Distribution:** This species exhibits late spring emergence (earliest record May 11) and has a widespread distribution (Fig. 6).
**Floral Records:** Robertson (1929): *Actinomeris, Agastache, Amorpha, Arabis, Astragalus, Baptisia, Bidens, Blephilia, Camassia, Campanula, Caulophyllum, Cephalanthus, Cercis, Collinsia, Cornus, Crataegus, Delphinium, Dentaria, Desmodium, Dicentra, Eupatorium, Frasera, Gerardia, Geranium, Gleditzia, Hibiscus, Houstonia, Hydrophyllum, Ipomoea, Iris, Justicia, Krigia, Liatris, Lobelia, Lythrum, Mertensia, Monarda, Nelumbo, Penstemon, Petalostemon, Phlox, Podophyllum, Polemonium, Prunella, Prunus, Pediomelum, Pycnanthemum, Pyrus, Rudbeckia, Salix, Scutellaria, Sisyrinchium, Spiraea, Symphoricarpos, Symphyotrichum, Teucrium, Tradescantia, Triodanis, Verbena, Vernonia, Viburnum, Viola, Vitis, Uvularia, Zizia.*
Macfarlane (1974): *Aesculus hippocataneum\*, Carduus nutans\*, Echium vulgare\*, Helianthus annuus\*, Hesperis matrònalis\*, Hydrophyllum virginianum, Hypericum perforatum\*, Linaria vulgaris\*, Lonicera tatarica\*, Melilotus alba\*, Medicago sativa\*, Pyrus malus\*, Robinia fertilis\*, Solanum dulcamara\*, Solidago canadensis, Solidago sempervirens, Symphyotrichum novae-angliae, Symphytum officinale\*, Syringa vulgaris\*, Taraxacum officinale\*, Trifolium pratense\*, Vicia cracca\*.*
Field and Museum Records: *Aesculus glabra, Asclepias incarnata, Asclepias syriaca, Asclepias tuberosa, Clinopodium vulgare, Echinacea, Eupatorium dubium, Eupatorium perfoliatum, Heliopsis helianthoides, Hypericum prolificum, Lactuca canadensis, Onopordum acanthium\*, Pontederia cordata, Rudbeckia hirta, Vaccinium angustifolium, Vaccinium corymbosum, Vaccinium myrtilloides, Urticularia vulgaris.*
**Habitats**: Open farmland and fields, urban parks and gardens, wetlands.

## *Bombus fervidus* Fabricius: the yellow bumble bee
**Phenology and Distribution:** This species exhibits mostly late spring emergence with a long colony cycle extending into autumn and has a widespread distribution (Fig. 7). The accumulated database contained only one single queen record in April with an unknown date. The majority of queen records were from May and June.
**Floral Records:** Macfarlane (1974): *Ajuga genevensis\*, Ajuga reptans\*, Aesculus hippocataneum\*, Caragana arborescens\*, Carduus nutans\*, Centaurea jacea\*, Cichorium intybus\*, Cirsium arvense\*, Delphinium, Dipsacus sylvestris\*, Echium vulgare\*, Gleditzia, Hydrophyllum virginianum, Iris, Kalmia latifolia, Kolkwitzia amabilis\*, Lactuca canadensis, Lathyrus latifolius\*, Linaria vulgaris\*, Lonicera caerulea, Lonicera tatarica\*, Lotus corniculatus\*, Malus, Melilotus alba\*, Medicago sativa\*, Monarda didyma, Nepeta cataria\*, Onobrychis viciifolia\*, Onopordum acanthium\*, Potentilla, Prunella vulgaris\*, Pyrus malus\*, Ribes odoratum, Robinia fertilis\*, Salix, Solanum dulcamara\*, Solidago canadensis, Solidago graminifolia, Symphyotrichum novae-angliae, Symphytum officinale\*, Syringa vulgaris\*, Taraxacum officinale\*, Trifolium pratense\*, Tulipa\*, Vicia cracca\*, Weigelia florida\*.*
Field and Museum Records: *Centaurea maculosa\*, Erigeron, Euthamia graminifolia, Inula*

*helenium\*, Lobelia cardinalis, Lonicera, Lythrum salicaria\*, Melilotus alba\*, Penstemon digitalis, Pontederia cordata, Securigera varia\*, Solidago, Sonchus oleraceus\*, Spiranthes, Urticularia vulgaris.*
**Habitats**: Open farmland and fields.

### *Bombus ternarius* Say: the tri-coloured bumble bee

**Phenology and Distribution:** This species exhibits early spring emergence (earliest record April 15) and has a widespread distribution except in extreme southwestern Ontario (Fig. 8).
**Floral Records:** Macfarlane (1974): *Salix discolor.*
Field and Museum Records: *Aralia, Aralia hispida, Aralia nudicaulis, Astragalus canadensis, Chamaedaphne calyculata, Cirsium vulgare\*, Claytonia caroliniana, Cynoglossum officinale\*, Echium vulgare\*, Epilodium angustifolium, Erythronium albidum, Eupatorium fistulosum, Eupatorium maculatum, Eurybia macrophylla, Euthamia graminifolia, Hypericum perforatum\*, Impatiens capensis, Ledum groenlandicum, Medicago sativa\*, Melilotus alba\*, Mentha, Monarda, Pilosella aurantiaca\*, Prunus pensylvanica, Rhexia virginica, Securigera varia\*, Solidago altissima, Solidago canadensis, Solidago juncea, Spiraea, Spiraea alba, Symphyotrichum novae-angliae, Symphyotrichum puniceum, Syringa vulgaris\*, Tanacetum vulgare\*, Taraxacum officinale\*, Tilia americana, Trifolium hybridum\*, Trifolium pratense\*, Trillium grandiflorum, Urticularia vulgaris, Vaccinium angustifolium, Verbascum thapsus\*, Verbena hastata, Vicia cracca\*.*
**Habitats:** Close to or within wooded areas.

### *Bombus rufocinctus* Cresson: the red-belted bumble bee

**Phenology and Distribution:** This species exhibits late spring emergence (earliest record May 28) and has a widespread distribution with more records in the Greater Golden Horseshoe region (Fig. 9).
**Floral Records:** Macfarlane (1974): *Lactuca canadensis, Potentilla, Symphyotrichum (Aster) lateriflorum.*Field and Museum Records: *Apocynum androsaemifolium, Arctium minus\*, Campanula, Centaurea maculosa\*, Cichorium intybus\*, Cirsium arvense\*, Daucus carota\*, Echium vulgare\*, Eupatorium, Eupatorium fistulosum, Eupatorium maculatum, Geranium, Helianthus, Heracleum lanatum, Hypericum prolificum, Inula helenium\*, Lupinus, Medicago sativa\*, Melilotus alba\*, Mentha, Monarda fistulosa, Prunella vulgaris\*, Rubus, Securigera varia\*, Solidago, Solidago altissima, Solidago bicolor, Syringa vulgaris\*, Trifolium pratense\*, Trifolium repens\*, Verbena hastata, Vicia cracca\*.*
**Habitats:** Close to or within wooded areas, urban parks and gardens.

### *Bombus affinis* Cresson: the rusty-patched bumble bee

**Phenology and Distribution:** This species exhibits early spring emergence (earliest record April 20) with a long colony cycle extending into the autumn and has a southern distribution with fewer recent records (Fig. 10).
**Floral Records:** Macfarlane (1974): *Arctium minus\*, Asclepias syriaca, Berberis thunbergii\*, Carduus nutans\*, Centaurea cyanus\*, Cotoneaster adpressa\*, Crataegus, Cucumis melo\*, Deutzia gracilis\*, Echium vulgare\*, Hydrophyllum virginianum,*

*Hypericum perforatum\*, Impatiens campensis, Kalmia latifolia, Linaria vulgaris\*, Lonicera caerulea, Lonicera periclymenum\*, Lonicera tatarica\*, Lotus corniculatus\*, Melilotus alba\*, Medicago sativa\*, Nepeta cataria\*, Prunus americana, Prunus cerasus\*, Prunus tomentosa\*, Pyrus malus\*, Rhododendron, Ribes grossularia\*, Ribes nigrum\*, Ribes rubrum\*, Robinia fertilis\*, Rubus, Salix, Silene dichotoma\*, Solanum dulcamara\*, Solidago canadensis, Solidago flexicaulis, Sonchus oleraceus\*, Stachys palustris\*, Symphyotrichum (Aster) ericoides, Symphyotrichum (Aster) lateriflorum, Symphyotrichum novae-angliae, Symphytum officinale\*, Syringa vulgaris\*, Taraxacum officinale\*, Trifolium pratense\*, Trifolium repens\*, Vicia cracca\*, Vinca minor\*, Weigelia florida\*.*
**Field and Museum Records:** *Eupatorium maculatum, Eupatorium perfoliatum, Eupatorium rugosum, Euthamia graminifolia, Helianthus decapetalus, Helianthus divaricatus, Kalmia, Onopordum acanthium\*, Rhexia virginica, Rhus, Spiraea, Vaccinium angustifolium, Vaccinium vacillans.*
**Habitats:** Close to or within wooded areas, open fields, urban parks and gardens.

### *Bombus citrinus* Smith: the lemon cuckoo bumble bee
**Phenology and Distribution:** Males and females of this species are found from early spring until late autumn and this species has a widespread distribution (Fig. 11). The earliest spring record is a female collected on April 26.
**Floral Records:**  Robertson (1929): *Blephilia, Verbena.*
Field and Museum Records: *Centaurea jacea\*, Cephalanthus occidentalis, Cirsium vulgare\*, Daucus carota\*, Epilobium, Eupatorium fistulosum, Eupatorium maculatum, Eupatorium perfoliatum, Euthamia graminifolia, Helianthus, Melilotus alba\*, Prunella vulgaris\*, Solidago, Solidago altissima, Solidago bicolor, Symphyotrichum (Aster) ericoides, Trifolium pratense\*, Verbena hastata, Vicia cracca\*.*
**Habitats:** Close to or within wooded areas.

### *Bombus ashtoni* Cresson: Ashton's cuckoo bumble bee
**Phenology and Distribution:** Males and females of this species are found from early spring until late autumn (Fig. 12).  Recent occurrences of this species in Ontario are scarce. The earliest spring record is a female collected on April 21.
**Floral Records:** Field and Museum Records: *Allium, Aralia, Cephalanthus, Eupatorium, Inula helenium\*, Melilotus alba\*, Penstemon, Pilosella aurantiaca\*, Rubus, Solidago, Solidago canadensis, Symphyotrichum novae-angliae, Syringa vulgaris\*, Taraxacum officinale\*, Trifolium hybridum\*, Trifolium pratense\*, Vaccinium angustifolium, Vaccinium corymbosum.*
**Habitats:** Close to wooded areas.

### *Bombus borealis* Kirby: the northern amber bumble bee
**Phenology and Distribution:** This species exhibits late spring emergence (earliest record May 14) and is sparsely distributed across southern Ontario (Fig. 13).
**Floral Records:** Field and Museum Records: *Astragalus canadensis, Cirsium vulgare\*, Echium vulgare\*, Eupatorium fistulosum, Inula helenium\*, Medicago sativa\*, Melilotus alba\*, Onopordum acanthium\*, Rubus, Solidago, Symphyotrichum novae-angliae, Trifolium pratense\*, Vicia cracca\*.*

**Habitats:** Close to or within wooded areas.

### *Bombus pensylvanicus* DeGeer: the American bumble bee

**Phenology and Distribution:** This species exhibits late spring emergence (earliest record May 15) and is mostly distributed in southernmost regions where it is at the northern edge of its range (Fig. 14).

**Floral Records:** Robertson (1929): *Amelanchier, Amorpha, Antennaria, Asclepias, Astragalus, Baptisia, Blephilia, Campanula, Cephalanthus, Cerastium, Cercis, Circaea, Claytonia, Clematis, Collinsia, Coreopsis, Cornus, Crataegus, Delphinium, Desmodium, Dentaria, Dicentra, Frasera, Gaura, Gentiana, Geranium, Gerardia, Gymnocladus, Helenium, Helianthus, Heliopsis, Heuchera, Hibiscus, Hydrophyllum, Impatiens, Ipomoea, Iris, Krigia, Lespedeza, Lithospermum, Lobelia, Ludwigia, Lycopus, Mertensia, Mimulus, Monarda, Nelumbo, Oenothera, Orobanche, Oxalis, Petalostemum, Penstemon, Phlox, Physostegia, Plantago, Podophyllum, Polemonium, Polygonatum, Polygonum, Polytaenia, Potentilla, Prenanthes, Prunella, Prunus, Pycnanthemum, Rhamnus, Ribes, Rubus, Rudbeckia, Ruellia, Sagittaria, Salix, Scutellaria, Sida, Silene, Silphium, Sium, Solidago, Stachys, Staphylea, Strophostyles, Symphoricarpos, Teucrium, Tilia, Tradescantia, Triosteum, Uvularia, Verbascum, Verbesina, Verbena, Vernonia, Veronica, Viburnum, Viola, Zizia.*

Macfarlane (1974): *Althaea rosea\*, Carduus nutans\*, Dipsacus sylvestris\*, Echium vulgare\*, Erigeron philadelphicus, Symphyotrichum novae-angliae, Hesperis matronalis\*, Hydrophyllum virginianum, Kalmia latifolia, Lonicera tatarica\*, Medicago sativa\*, Pyrus malus\*, Robinia fertilis\*, Solidago flexicaulis, Solidago graminifolia, Sonchus oleraceus\*, Symphytum officinale\*, Syringa vulgaris\*, Trifolium pratense\*, Vaccinium angustifolium, Vicia cracca\*, Weigelia florida\*.*

Field and Museum Records: *Astragalus canadensis, Campsis, Decodon, Dasistoma, Echinacea, Euthamia graminifolia, Justicia, Lupinus,  Pontederia cordata, Pediomelum, Rubus idaeus, Symphyotrichum, Triodanis.*

 **Habitats:** Open farmland and fields.

### *Bombus insularis* Smith: indiscriminate cuckoo bumble bee

**Phenology and Distribution:** Males and females of this species are found from late spring until early autumn (Fig. 15).  Records of this species are across southern Ontario but are scarce.  The earliest spring record is for a female collected on May 30.

**Floral Records** Field and Museum Records: *Centaurea maculosa\*, Eupatorium maculatum, Melilotus alba\*, Rubus, Solidago, Trifolium pratense\*, Trifolium repens\*, Vaccinium angustifolium, Vicia cracca\*.*

**Habitats:** Unknown.

### *Bombus auricomus* Robertson: the black and gold bumble bee

**Phenology and Distribution:** This species exhibits mid-spring emergence (earliest record May 5) and has mostly a southwestern distribution (Fig. 16).

**Floral Records** Field and Museum Records: *Dipsacus fullonum\*, Eupatorium perfoliatum, Hypericum, Malus, Monarda, Penstemon, Rubus occidentalis, Solanum dulcamara\*, Trifolium pratense\*.*

**Habitats:** Open farmland and fields.

### *Bombus sandersoni* Franklin: Sanderson's bumble bee
**Phenology and Distribution:** Few records exist for this species, consequently little is known on its distribution and phenology (Fig. 17). The earliest spring record for this species is June 2 in southern Ontario, indicating it may be a later emerging species.
**Floral Records:** Field and Museum Records: *Epilobium, Gaylussacia, Kalmia angustifolia, Kalmia polifolia, Lonicera, Malus, Monarda, Penstemon, Rhododendron, Rubus, Salix, Sarracenia purpurea, Scutellaria lateriflora*
**Habitats:** Unknown.

### *Bombus fernaldae* Franklin: Fernald's cuckoo bumble bee
**Phenology and Distribution:** Very few records exist for this species in the region, consequently little is known on its distribution and phenology (Fig. 18). The earliest spring record for this species is May 27 in southern Ontario.
**Floral Records:** Field and Museum Records: *Asclepias, Aster, Helianthus, Pilosella aurantiaca\*, Potentilla, Rubus, Solidago, Solidago hispida, Taraxacum officinale\*, Trifolium repens\*, Vaccinium angustifolium.*
**Habitats:** Unknown.

## Discussion

The bumble bees of southern Ontario differ in phenology, food plant choice, abundance and habitat selection. Unlike some invertebrate pollinators, bumble bees in southern Ontario are food generalists, foraging on a variety of native plant genera. For example, *B. impatiens*, the most common species in the region (Fig. 1), has been found visiting over 100 native plant genera throughout its range. This is likely due to their long colony life-cycles which span the flowering cycles of more than one plant species. Broad diet tolerances allows for behavioural flexibility in highly competitive situations where nectar is often a limiting resource (Fontaine et al. 2008). Differences in food choice are a major factor in niche partitioning among bumble bees in Ontario (Harder 1985).

This review indicates species in southern Ontario are often associated with particular habitat types and associated phenologies. Interestingly, the earliest emerging species (i.e. *B. bimaculatus, B. ternarius, B. perplexus, B. affinis, B. vagans, B. impatiens, B terricola*) are all associated with wooded habitats (Figs. 1-5, 8, 10). These species likely have co-evolutionary relationships with woodland spring ephemerals. Species associated with open fields tend to be later emerging species (i.e. *B. auricomus, B. griseocollis, B. pensylvanicus,* and *B.fervidus*) and are likely more reliant on later blooming field flowers (Figs. 6, 7, 14, 16). It has been suggested that later emerging species may be more vulnerable to stressors such as habitat loss (Williams et al. 2009).

Although this study focuses on natural history, some comments can also be made on species abundances. These data presented are consistent with previous findings that *B. impatiens* and *B. bimaculatus* are the most abundant species in southern Ontario (Colla and Packer 2008). Whether this was historically the situation or the consequence of their

tolerance of urbanized habitats remains to be determined. In contrast, many species have few records and are both historically and recently uncommon. For some rarer taxa this may be because they are at the northern edge of their native ranges in southern Ontario (e.g. *B. auricomus* and *B. pensylvanicus*; Figs. 14, 16). Additionally, very few records exist for most of the socially parasitic species (i.e. *B. ashtoni, B. fernaldae, B. insularis*), which have likely been always rare and dependent on host abundances. Basic information on distribution, ecological requirements and phenology are still required for the rare and uncommon species to aid in the conservation of these potentially at-risk species (COSEWIC 2010). Additionally, to better understand this important group of bees, further study is needed on nesting requirements, queen overwintering requirements, mating behaviours and dietary breadth for all *Bombus* species in southern Ontario. Additional studies on changes in distribution and abundance over time will also better our understanding of the ecological needs of these native pollinators.

## Acknowledgements

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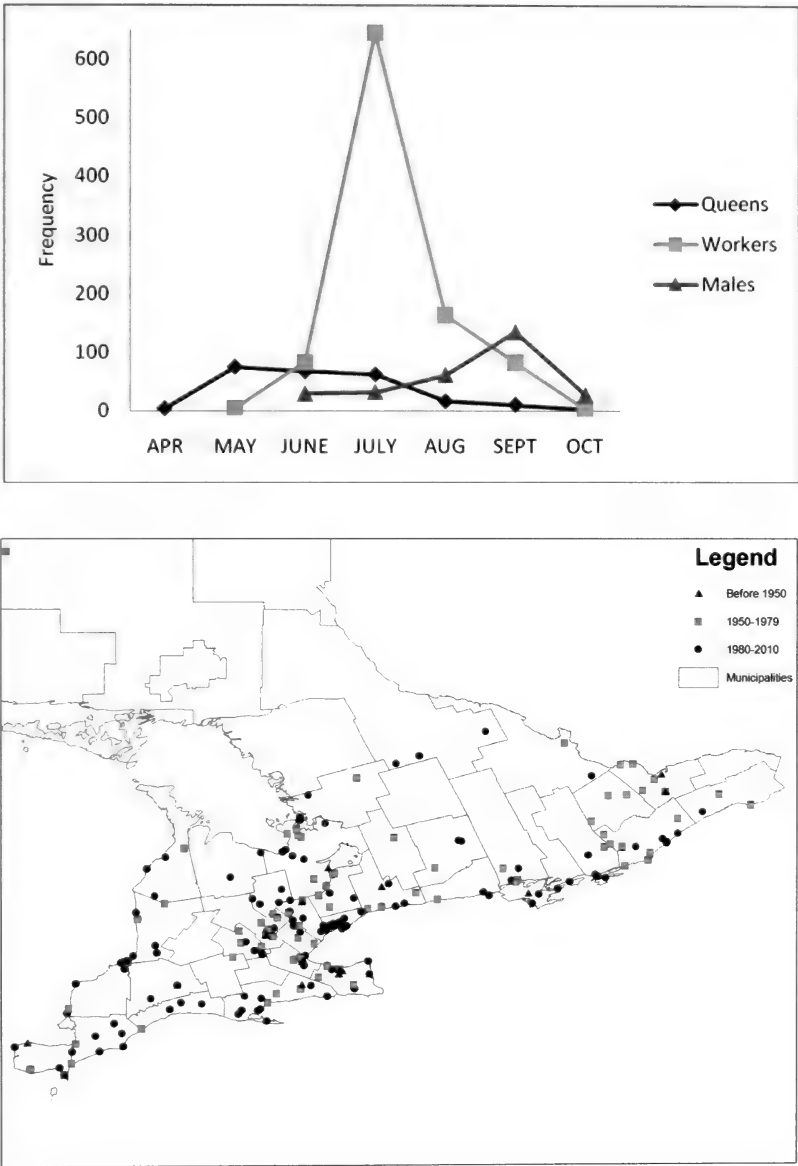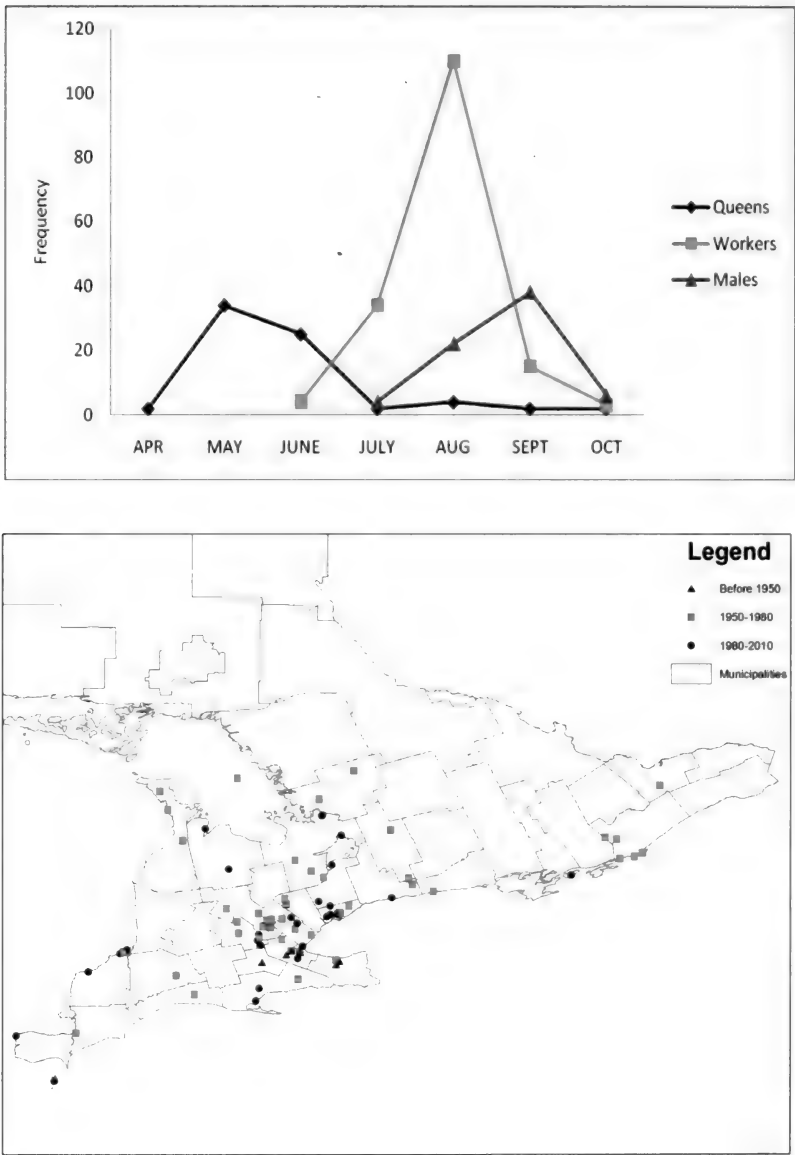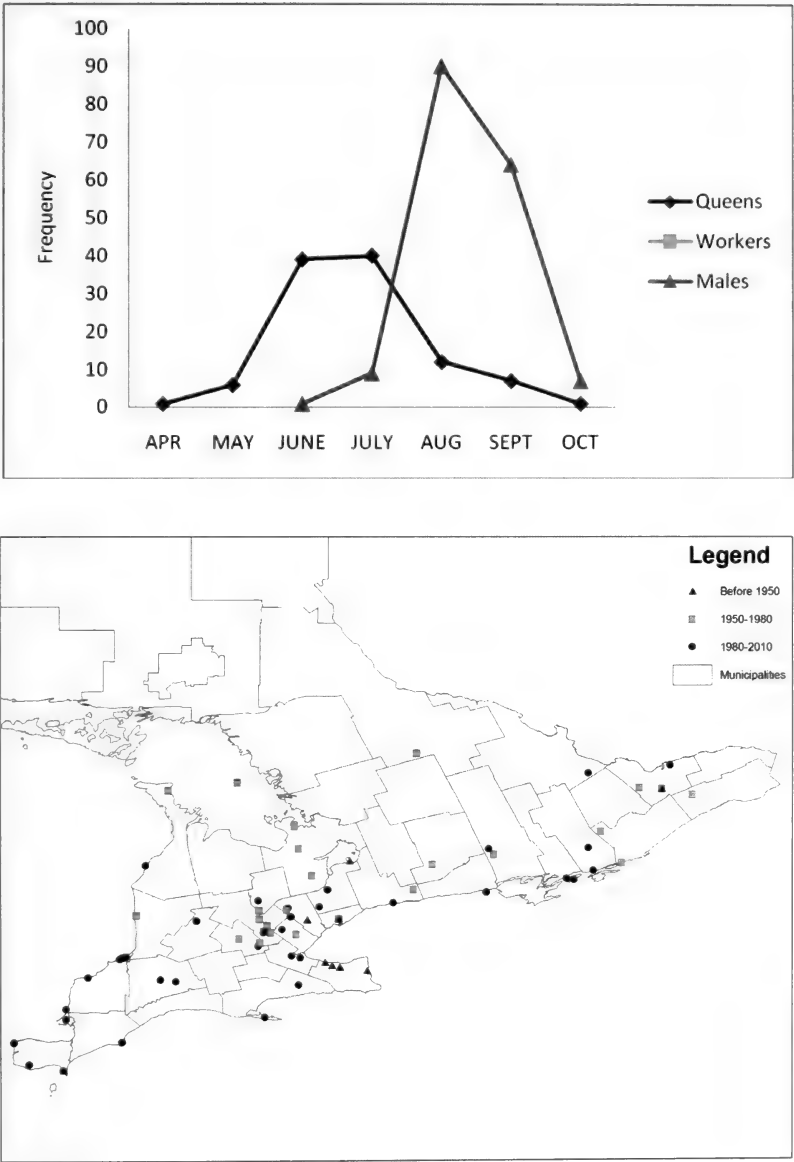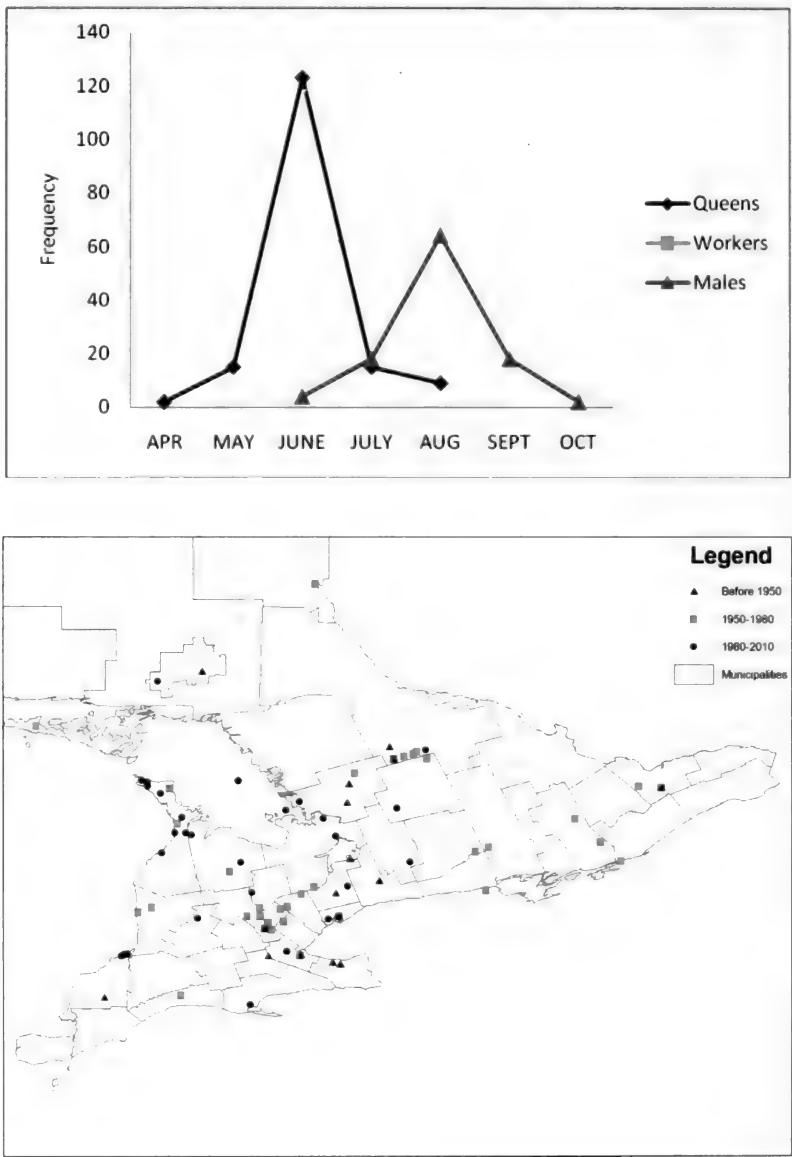
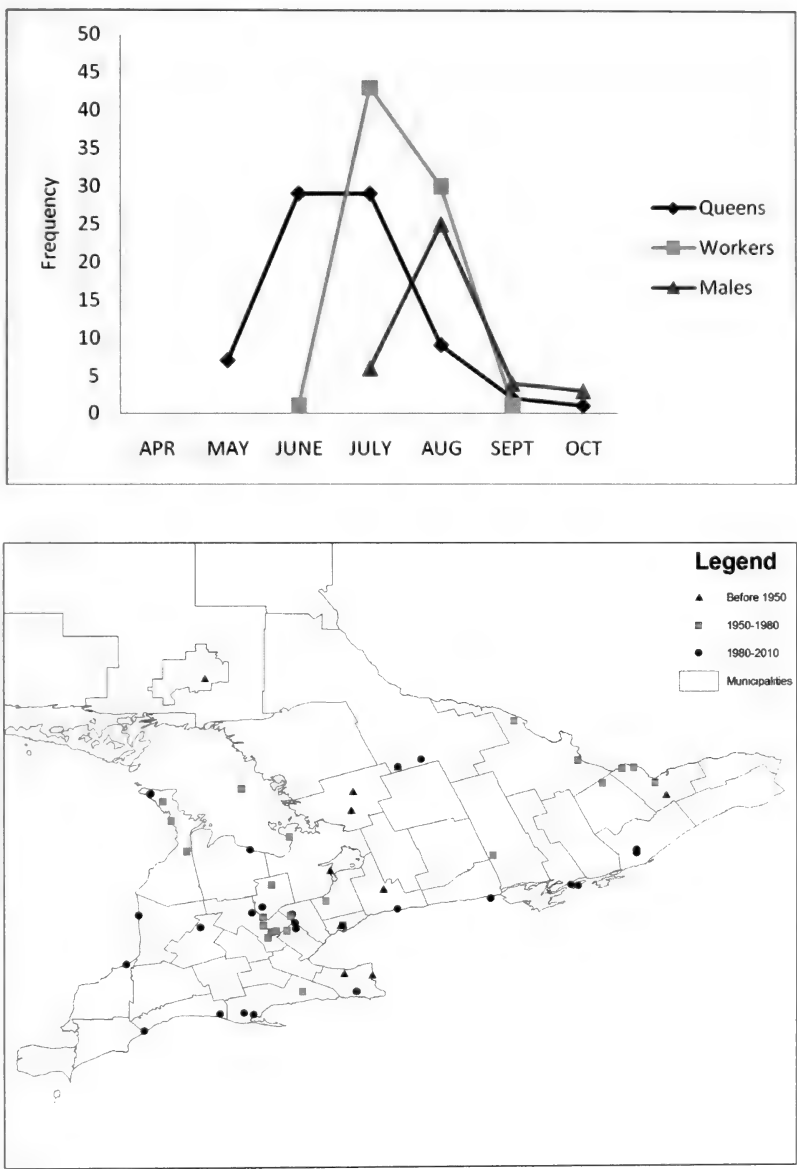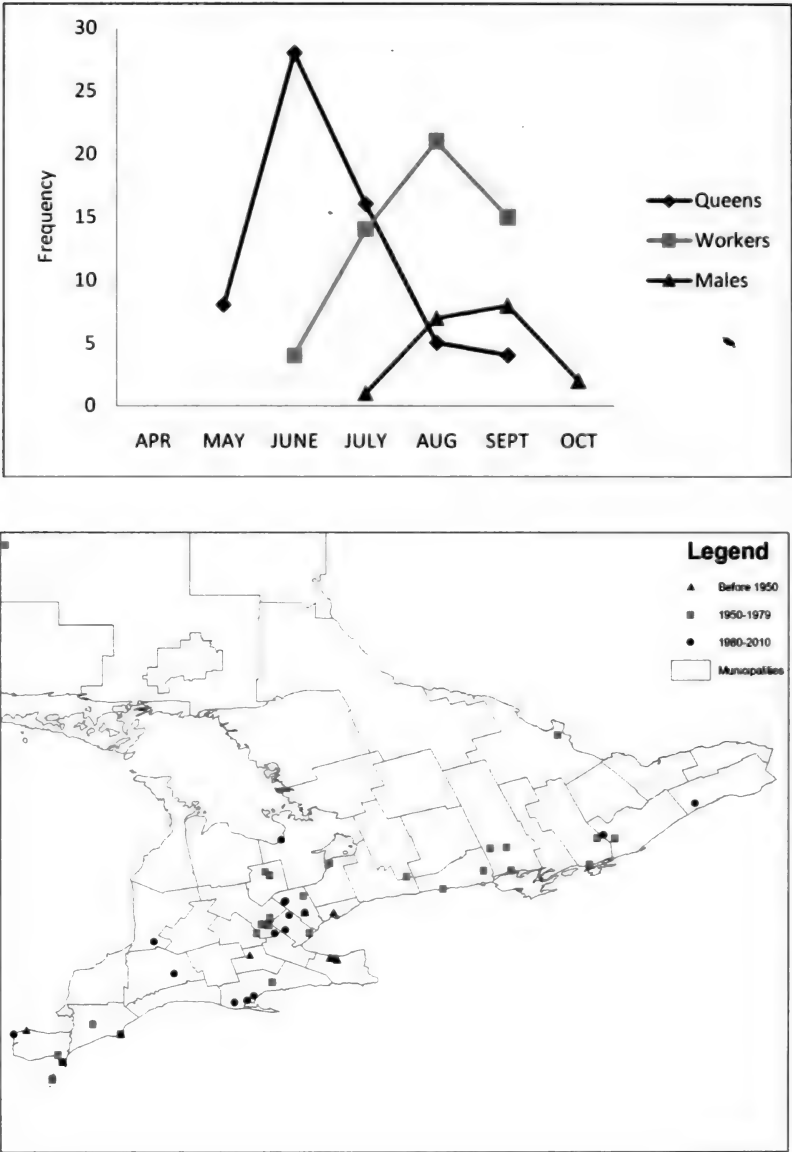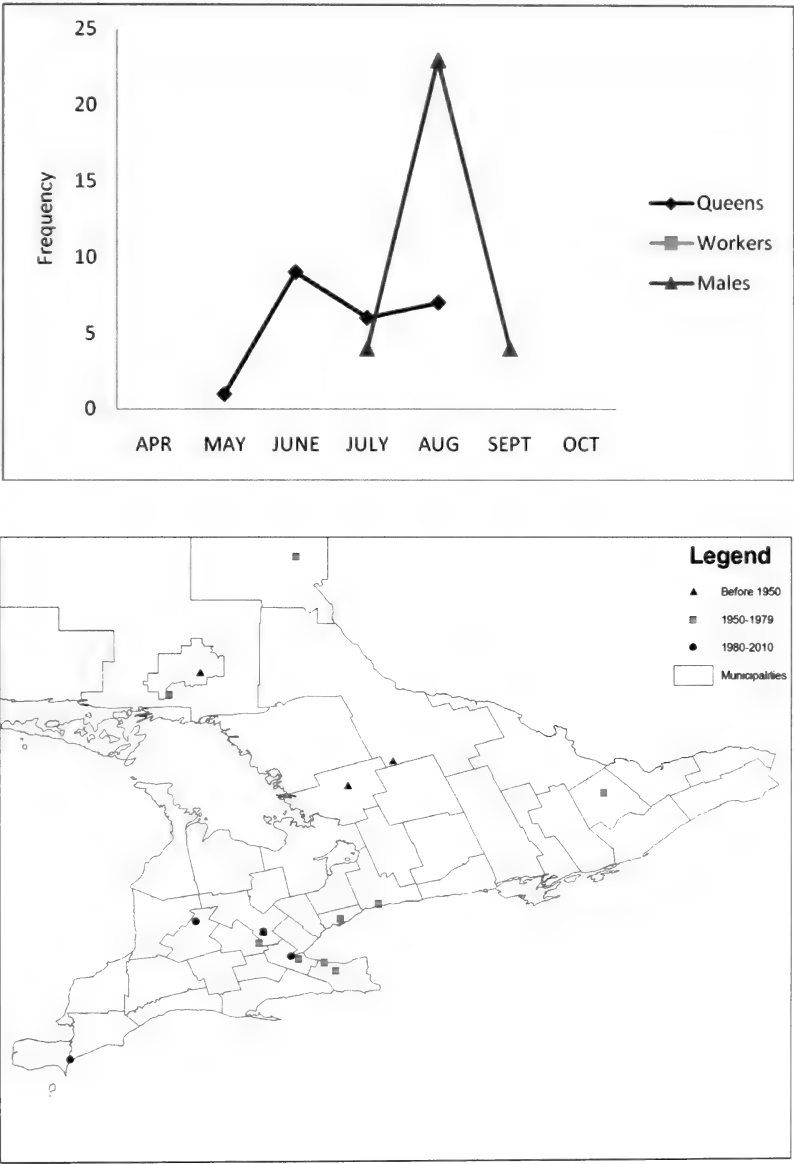FIGURE 1. Phenology and distribution for *Bombus impatiens* in southern Ontario (n=3017).
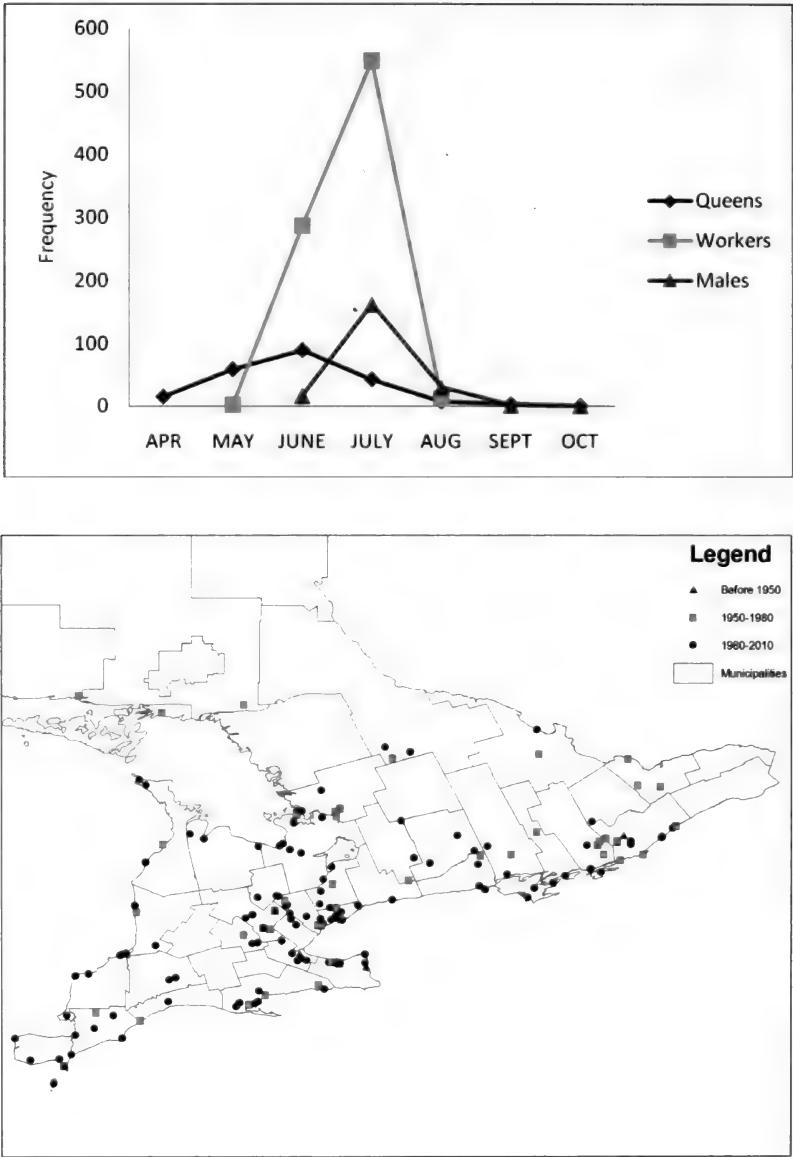
FIGURE 2. Phenology and distribution for *Bombus bimaculatus* in southern Ontario (n=1316).
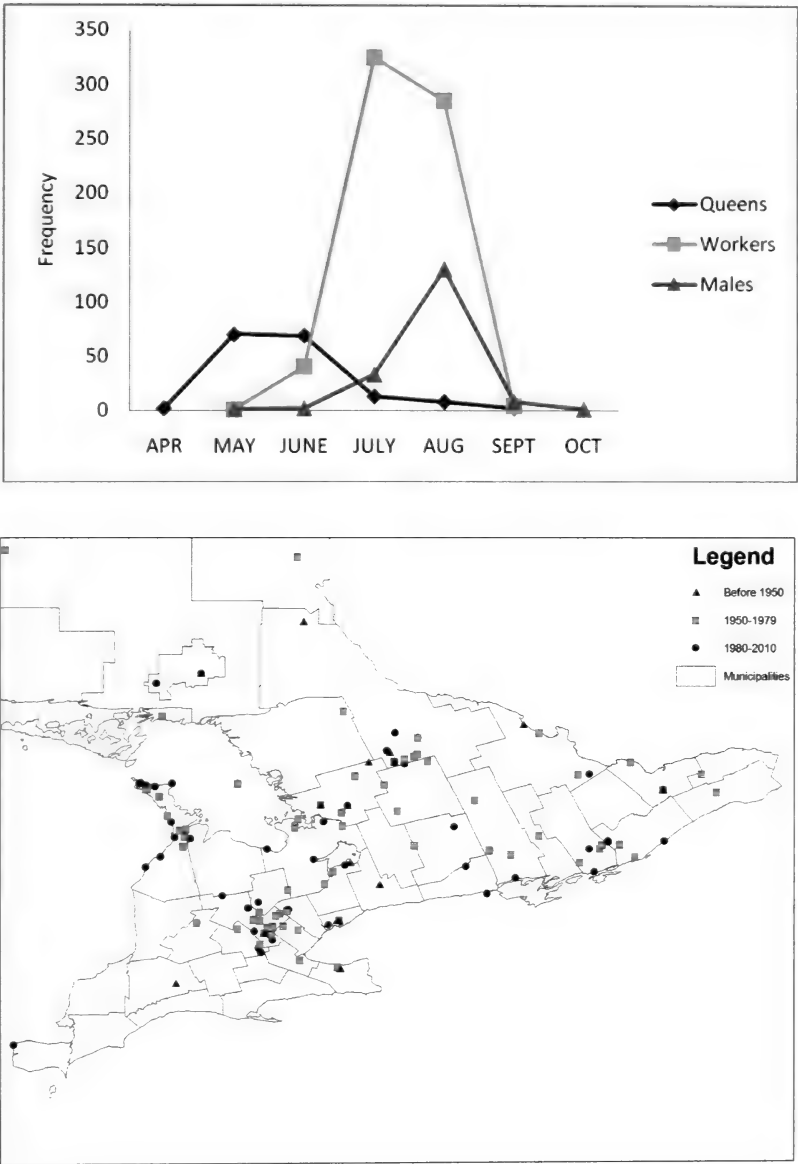
FIGURE 3. Phenology and distribution for *Bombus terricola* in southern Ontario (n=996).
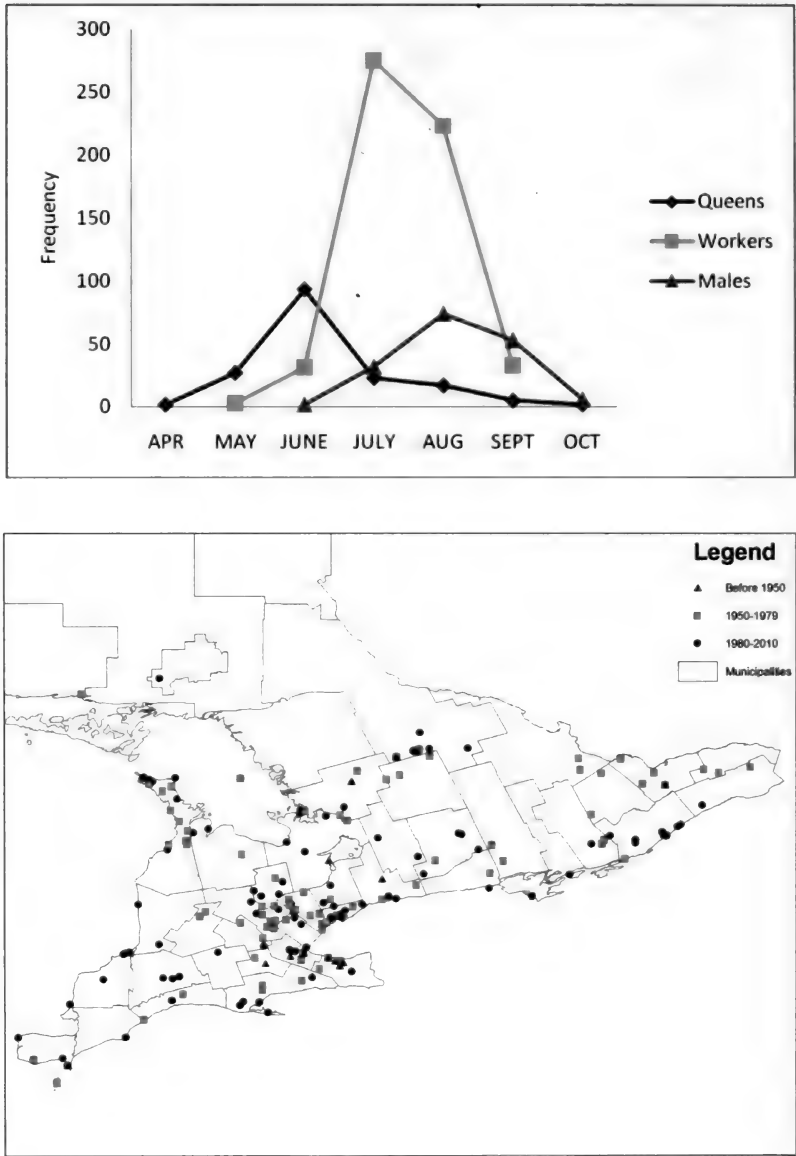
FIGURE 4. Phenology and distribution for *Bombus vagans* in southern Ontario (n=914).
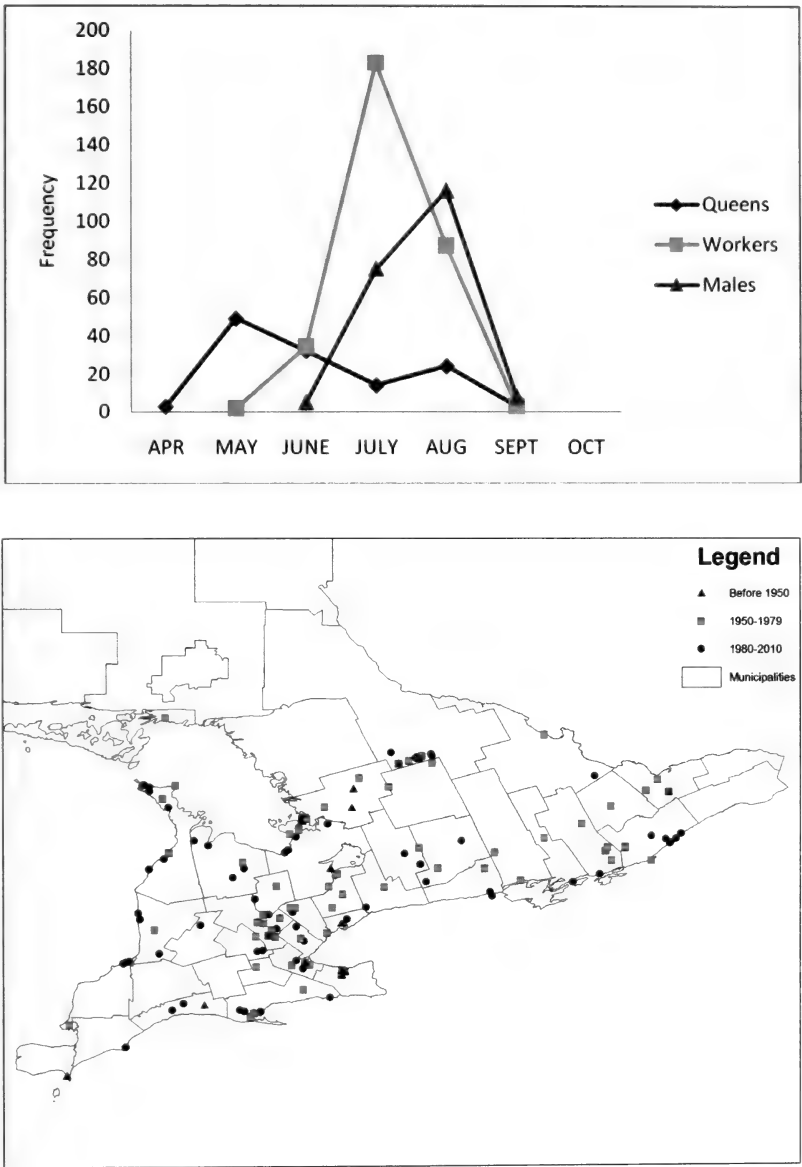
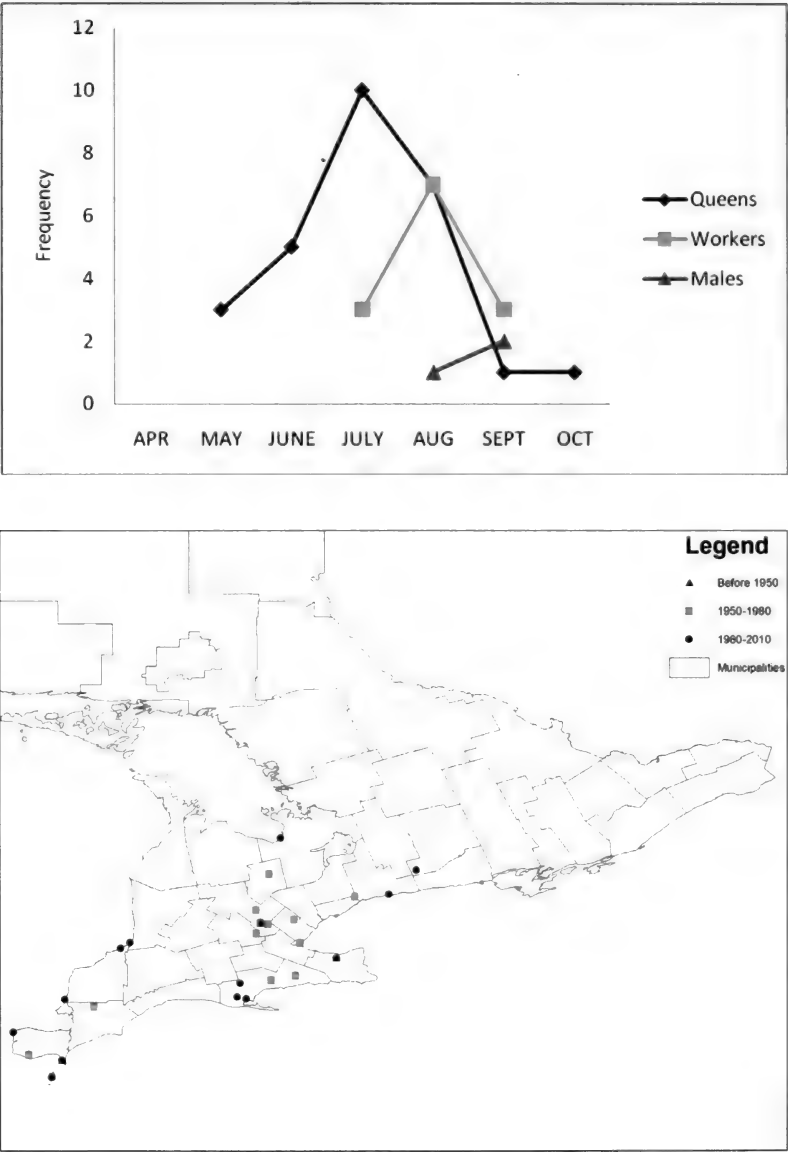FIGURE 5. Phenology and distribution for *Bombus perplexus* in southern Ontario (n=646).
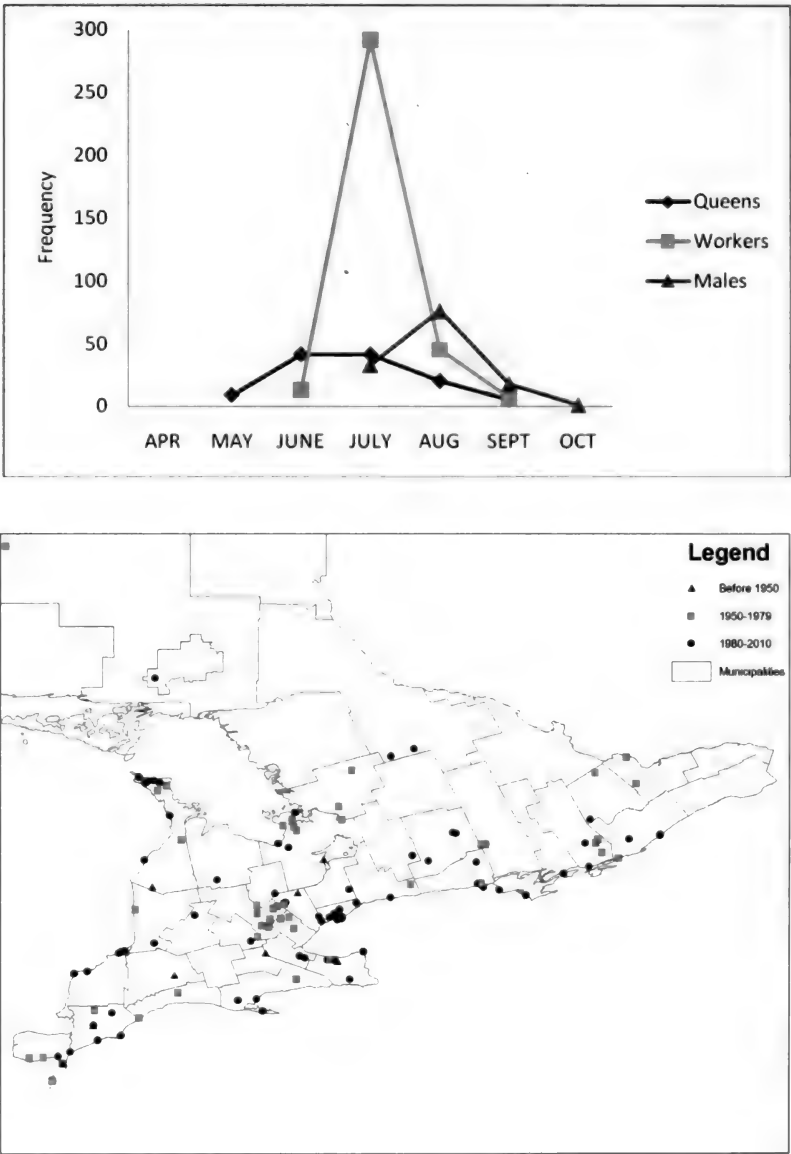
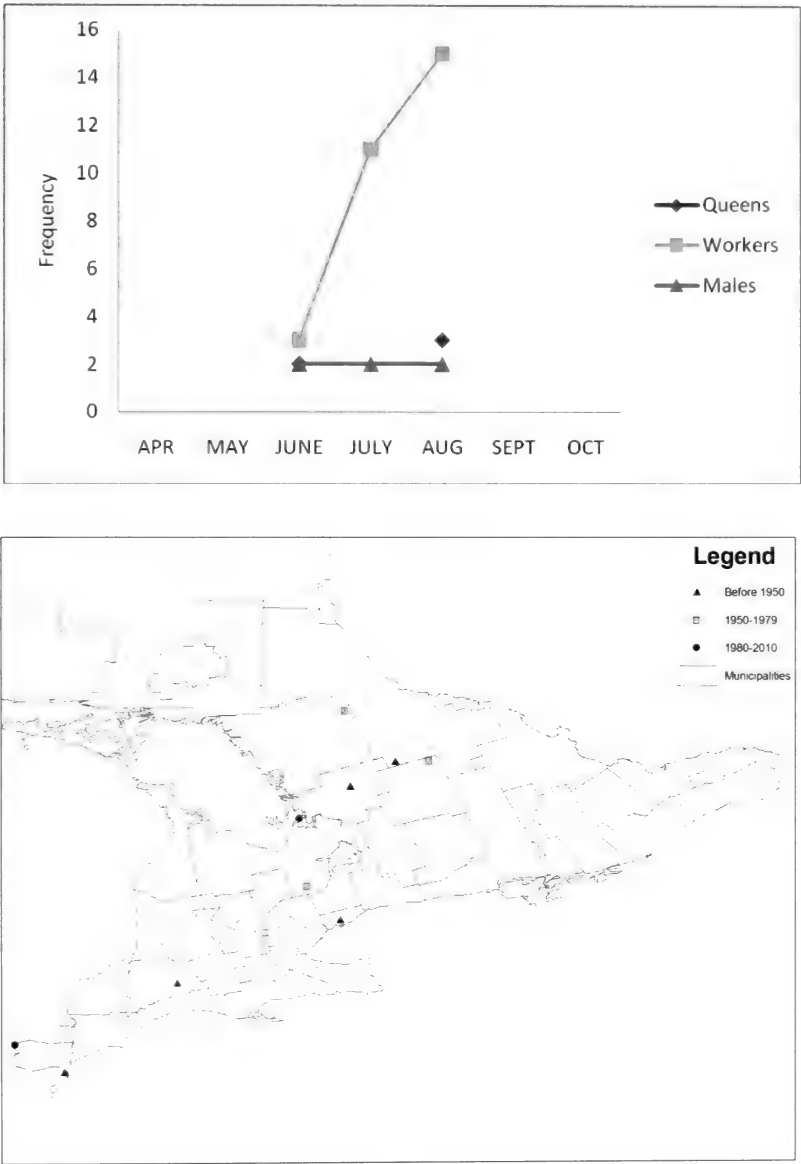FIGURE 6. Phenology and distribution for *Bombus griseocollis* in southern Ontario (n=611).
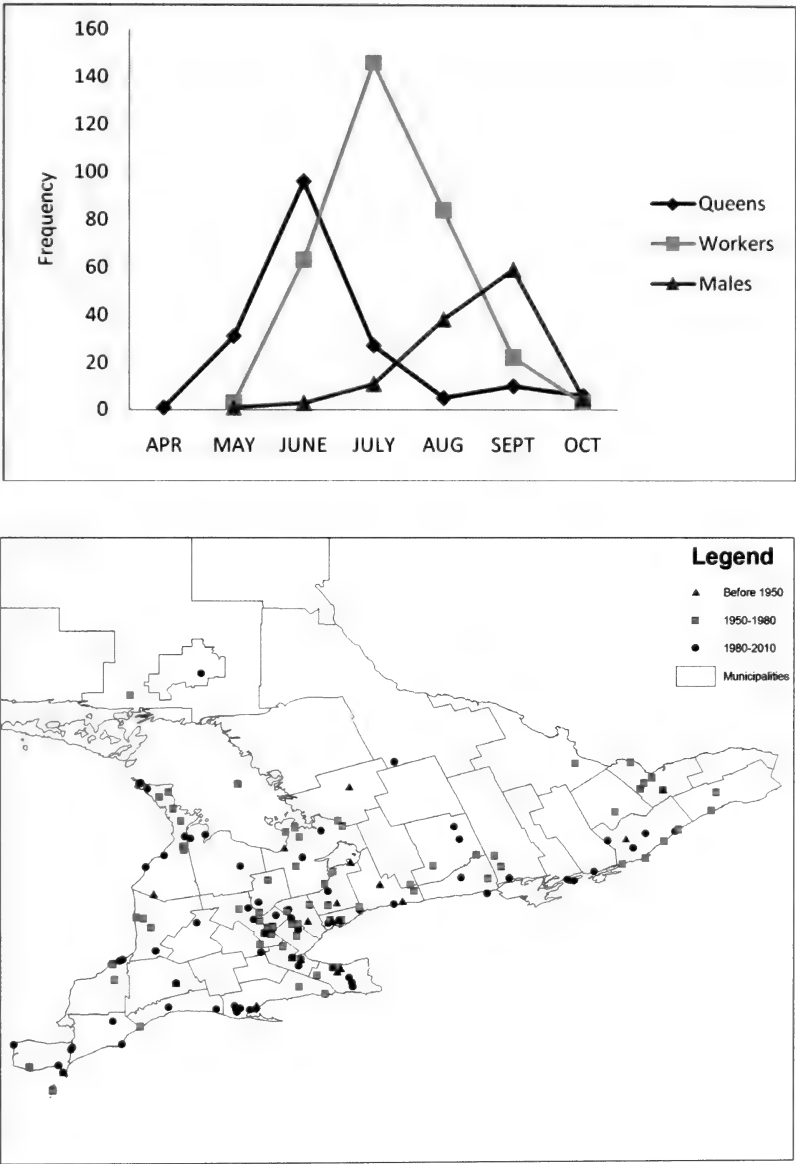
FIGURE 7. Phenology and distribution for *Bombus fervidus* in southern Ontario (n=585).
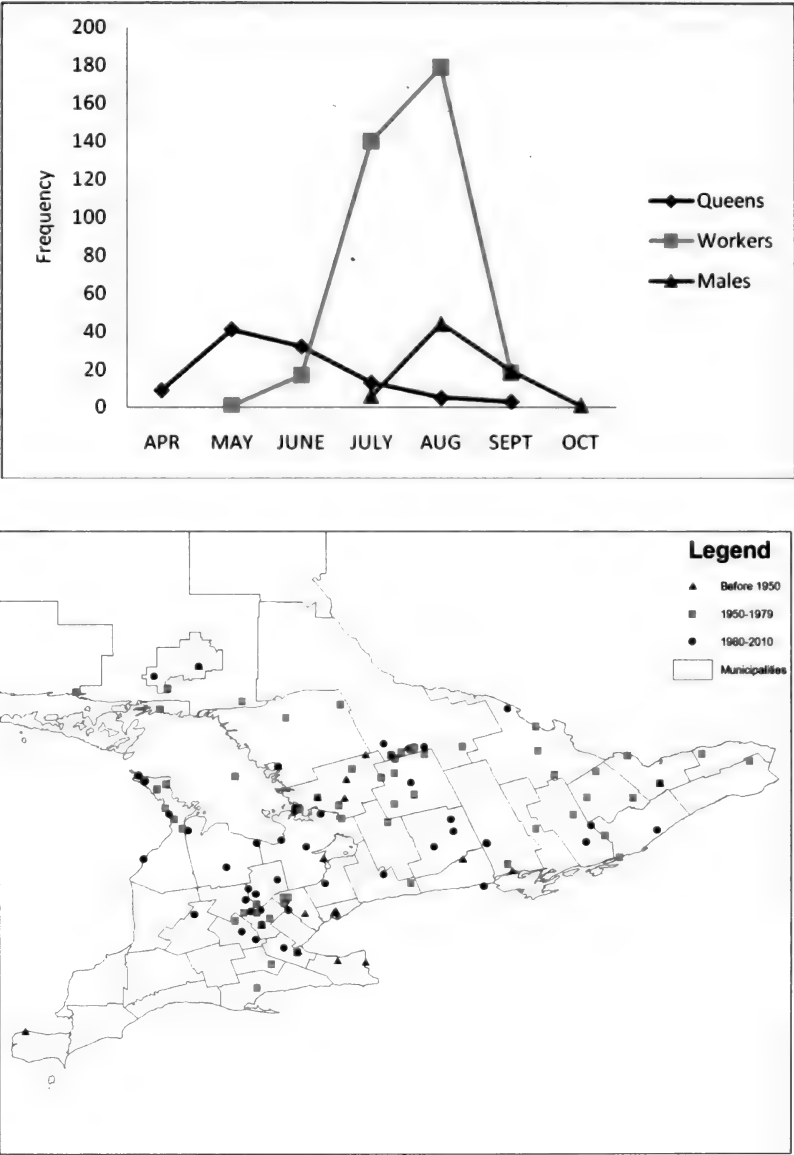
FIGURE 8. Phenology and distribution for *Bombus ternarius* in southern Ontario (n=534).
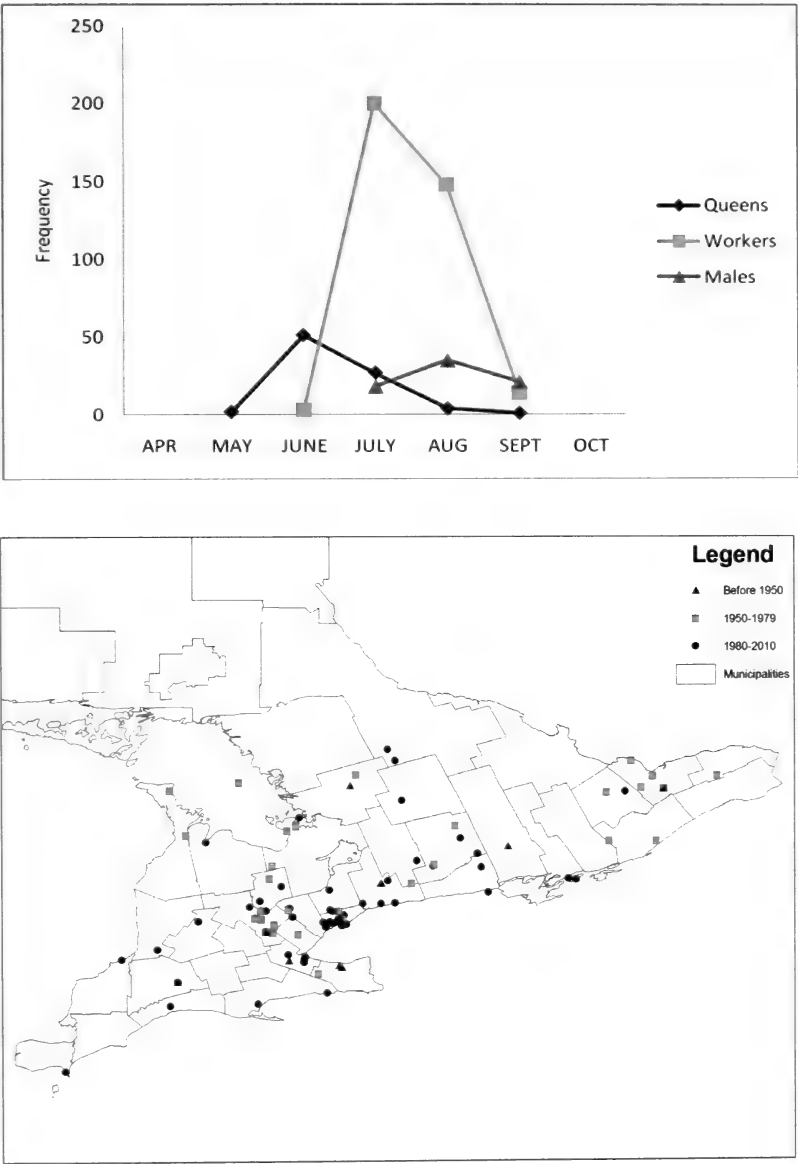
FIGURE 9. Phenology and distribution for *Bombus rufocinctus* in southern Ontario (n=527).

FIGURE 10. Phenology and distribution for *Bombus affinis* in southern Ontario (n=310).

FIGURE 11. Phenology and distribution for *Bombus citrinus* in southern Ontario (n=285).

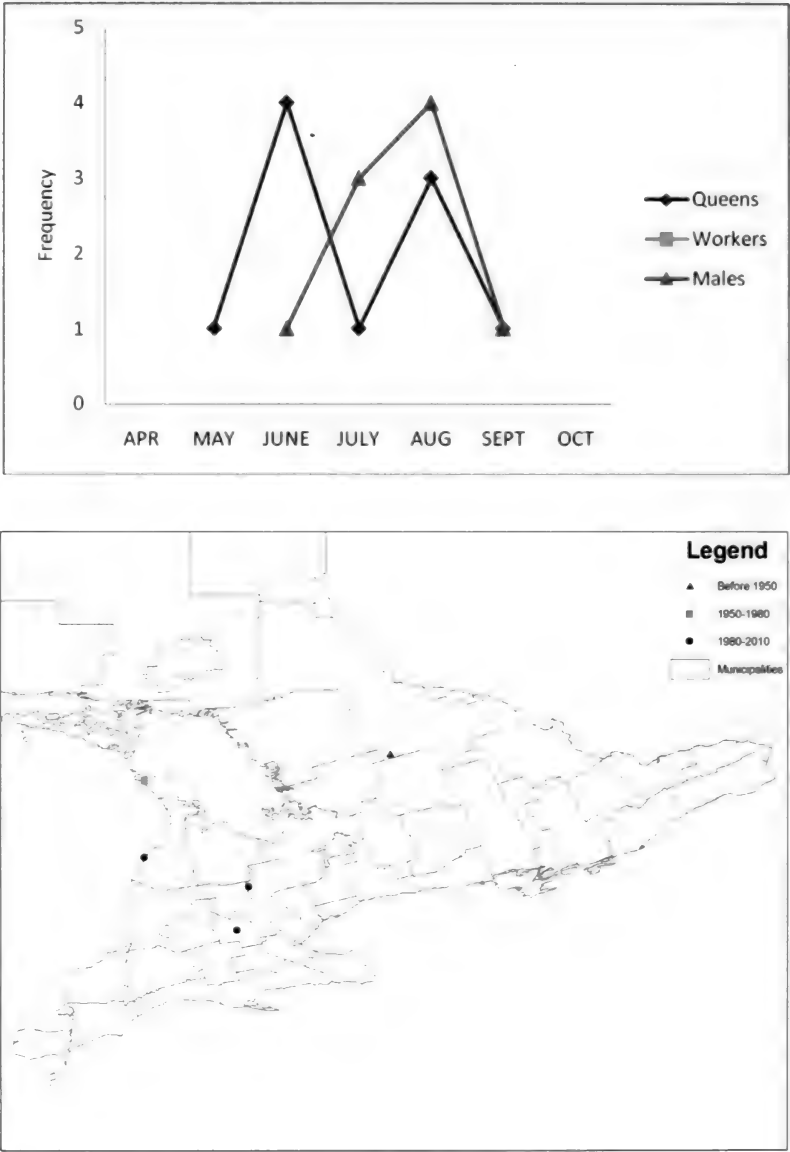FIGURE 12. Phenology and distribution for *Bombus ashtoni* in southern Ontario (n= 275).

FIGURE 13. Phenology and distribution for *Bombus borealis* in southern Ontario (n= 191).

FIGURE 14. Phenology and distribution for *Bombus pensylvanicus* in southern Ontario (n=135).

FIGURE 15. Phenology and distribution for *Bombus insularis* in southern Ontario  (n=54).

FIGURE 16. Phenology and distribution for *Bombus auricomus* in southern Ontario (n=43).

FIGURE 17. Phenology and distribution for *Bombus sandersoni* in southern Ontario (n=40).

FIGURE 18. Phenology and distribution for *Bombus fernaldae* in southern Ontario (n= 19).

# GROUND-DWELLING WEEVIL (COLEOPTERA: CURCULIONIDAE) COMMUNITIES IN FRAGMENTED AND CONTINUOUS HARDWOOD FORESTS IN SOUTH-CENTRAL ONTARIO

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**Abstract**                                      *J. ent. Soc Ont.* 141: 69- 83

Weevils (Coleoptera: Curculionidae) are the largest family in the animal kingdom and can be found in any habitat where plants grow. Many species not native to North America have invaded both anthropogenic and natural habitats, and the aim of this paper is to determine whether forest landscape continuity has discouraged introduced species. We compared the ground-dwelling weevil communities of hardwood forest fragments to those in hardwood stands in a continuously forested landscape, with the prediction that the fragments would have more introduced species. Pitfall traps caught 5090 individuals from 26 species. Both landscapes were dominated by introduced weevils (96% of all individuals), but forest fragments were dominated by *Barypeithes pellucidus* (Boheman), while *Sciaphilus asperatus* (Bonsdorff) represented 74% of all weevils caught in the continuous forest. Sixty-four percent of the introduced species were parthenogenetic, and all parthenogenetic species were polyphagous and flightless. Fifteen native species were captured but they accounted for only 4% of total individuals, and the only numerous native species, *Hormorus undulatus* (Uhler), was absent from the continuous forest. Seven native species were each represented by a single individual, one of which, *Sirocalodes sericans* (LeConte) is the first record for Ontario. Ground-dwelling weevil communities in central Ontario's forests are composed largely of non-native species, and relatively intact forests do not provide conservation protection for this group of invertebrates.

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# Introduction

The family Curculionidae (Coleoptera), hereafter weevils, is the largest family in the animal kingdom and contains about 51000 species worldwide, in 4600 genera (Anderson 1997; Oberprieler et al. 2007). As larvae and adults, almost all weevils are phytophagous, although a few species are saprophagous. While most of the phytophagous species are associated with angiosperms, weevils can be found in association with almost any terrestrial or freshwater plant species, and any plant part (Anderson 2002; Oberprieler et al. 2007). The largest subfamily, Entiminae, have larvae that mostly live in the soil and feed on roots. Both adult and larval entimines are largely polyphagous, feeding on many species of host plants. The other 17 subfamilies contain species whose larvae tend to live and feed inside plant parts including stems, leaves, roots and reproductive structures. These subfamilies also tend to have a more restricted range of host plants (monophagous or oligophagous), some limited to a single family, genus or species (Anderson 2002).

There are about 600 described weevil species in Canada, many of which are introduced (McNamara 1991). Most of the introduced species are of European origin (Langor et al. 2009) and most introductions are attributed to the importation of ornamental plants and other products, or to dry ballast (rock, soil and sand) dumped by British ships at North American seaports at the turn of the nineteenth century (Anderson 2002; Majka et al. 2007). Introduced weevils are prevalent in forested habitats. Pinski et al. (2005a) found 66.4% of all adult Curculionidae caught in northern hardwood forests in the Great Lakes region to be an introduced species (*Phyllobius oblongus* L.) and Coyle et al. (2008) reported a suite of nine invasive root-feeding weevils from this same region. Maerz et al. (2005) found one introduced weevil, *Barypeithes pellucidus* (Boheman), to be more abundant than all other beetle taxa combined in mature forest stands in New York and Pennsylvania. These past studies show the prevalence of introduced weevils in forests, but it is not known whether any large forest stands in Ontario provide refuge for native species.

Niemelä and Mattson (1996) argue that European phytophagous insects are better at invading North American forests than their North American counterparts are at invading European forests, especially in disturbed or fragmented landscapes where the plant communities are partially European in origin (Burke and Nol 1998). Periods of glaciation, more severe in Europe due to its topography than elsewhere in the world (Huntley 1993), and the past 6000 years of human habitation and exploitation (Ledig 1992) resulted in a long history of expansion and contraction of European forests. Through this volatility, traits having high survival-value in patchy landscapes were selected over those adapted to expansive forests. Armed with such traits as phenotypic plasticity, high reproductive potential, and stress-tolerance mechanisms, many introduced species have become the dominant phytophagous insects in their invaded niches (Niemelä and Mattson 1996).

Our objective is to compare the ground-dwelling weevil assemblages among forest fragments in an agricultural landscape and continuous forest in central Ontario, Canada. We predicted that forest fragments would have a greater proportion and higher abundances of introduced weevil species than stands found in a continuously forested landscape. We discuss the life history attributes of the weevils in light of their ability to become established in continuously forested landscapes.

## Materials and Methods

### Study Sites

*Forest Fragments* – Twenty-two mature deciduous woodlots in the southern portion of Peterborough County (44° 17' N, 78° 20' W) in central Ontario, Canada were selected as part of a broader study on forest-breeding birds. The region is part of the Great Lakes-St. Lawrence lowlands, at the southern edge of the Canadian Shield, in the Mixedwood Plains Ecozone of the Ecological Land Classification of Canada (AAFC 2010). The region experiences an average of 124 frost-free days a year, and 84 cm of precipitation (Environment Canada 2008). Elevation ranges from 75 to 408 m with an average of 305 m (Wickware and Rubec 1989). Though the soils in this region are variable in composition, all woodlots were located in well-drained loam or sandy-loam soils with layers of organic material 8-10 cm thick (Webber et al. 1946; Gillespie and Acton 1981). The landscape is composed of agriculture and forest fragments, interspersed with farms, housing developments, and wetlands (Phillips et al. 2005). On average, intensive agriculture (row-crops) accounted for 28% of the landscape within 2 km of the woodlots, less-intensive agriculture (hay, old fields, and pastures) accounted for 30%, and forest cover accounted for 24% (Richmond 2006). All 22 woodlots were dominated by *Acer saccharum* (Aceraceae), with *Fraxinus americana* (Oleaceae), *Ostrya virginiana* (Betulaceae), *Thuja occidentalis* (Cupressaceae), *Fagus grandifolia* (Fagaceae) and *Tilia americana* (Tiliaceae) all occurring as frequent canopy species. The woodlots ranged from 6.7 to 280.4 ha, with a mean of 37.1 ha. None of the woodlots had been recently exposed to grazing, logging, fire or construction (Phillips et al. 2005, Richmond 2006). The understory plant communities at the sampling points in forest fragments were largely native (S. Richmond, pers. obs.).

*Continuous Forest* – Nine mature hardwood stands in the southern portion of Algonquin Provincial Park (45° 35' N, 78° 29' W) in central Ontario, Canada were selected as part of a larger study on sustainable forest management. Algonquin Park lies in a transition zone between the boreal forest to the north and the Great Lakes-St. Lawrence lowlands to the south (Rowe 1972), in the Boreal Shield Ecozone of the Ecological Land Classification of Canada (AAFC 2010). The park covers an area of 7700km², the western two-thirds of which (about 4600km²) consists of tolerant hardwood forests over rugged terrain, interspersed with numerous lakes (Quinn 2004). Mean elevation is 396m, with the western portion of the park experiencing an average of 84 frost-free days a year, and 100cm of precipitation (Strickland 2006). Soils characteristic of the hardwood forests are fresh to moist, medium to coarse loams, with an average organic matter layer of 10cm (Chambers et al. 1997). All nine stands were characterized by canopies dominated by *Acer saccharum*, with lesser amounts of *Fagus grandifolia*, *Betula alleghaniensis* (Betulaceae), *Prunus serotina* (Rosaceae), and *Tsuga canadensis* (Pinaceae). Sites ranged from 14.4 to 54.8ha, with a mean of 35.8ha. Few non-native plant species occurred in these stands (E. Proctor, pers. obs.).

### Insect Sampling

Ground-dwelling invertebrates were sampled in all sites using pitfall traps, which consisted of 500ml containers dug into the ground so that the lips of the containers were

flush with the soil. The containers were filled halfway with water, a pinch of salt (as a preservative) and a few drops of dish soap (to disrupt surface tension). Each trap was covered with a wire grate to reduce small mammal and amphibian by-catch, and to discourage larger mammals from disturbing them.

Sampling in Peterborough County took place in the spring and summer of 2001, 2003 and 2004, and the number and layout of pitfall traps varied from year to year. In 2001, one trap was placed every 20m along a 100m transect that extended from the edge of the woodlot into the interior, for a total of six pitfalls per site. Traps were active from mid May until mid August, for a total of approximately 8800 trap-days. In 2003 and 2004, the transect was 50m long, with one trap placed every 5m from 0 to 20m, and then every 10m from 20 to 50m, for a total of eight traps per site. In 2003, sampling went continuously from late-May to late-July, for a total of approximately 8500 trap-days. In 2004, trapping began in June and continued until August, and traps were left inactive for six to seven days following each collection. This resulted in approximately 3600 trap-days. Thus, in the fragmented forest we had a sampling effort of 20,900 trap-days.

Sampling in Algonquin Provincial Park took place in the spring and summer of 2006 and 2007. Each of the nine stands had 12 pitfalls, placed in a three-by-four grid, with 10m between traps. Pitfalls were located in the centre of each stand and were active for two seven-day periods: once in late May and again in mid June, for a total of approximately 1500 trap-days per year for a total of 3000.

All invertebrates were rinsed and preserved in 70% ethanol upon collection. Weevils were later separated from the rest of the samples and identified to species. Voucher specimens were deposited at Trent University and the Canadian Museum of Nature. We characterized dominant species as those that represented 5% or more of the total number of specimens for a region.

## Analysis

To determine whether parthenogenesis or flightlessness were more prevalent in the introduced weevil species than in the native species caught in this study, we used Fisher's exact tests. When comparing communities, problems arise if sample sizes differ because larger samples are expected to contain a greater number of species. The Peterborough County sites were sampled more intensively than those in Algonquin Park, with sampling taking place throughout the growing season as compared to a week each in late-May and mid-June. We used rarefaction to standardize all samples to a common sample size by estimating the number of species expected in a random sample of individuals taken from a collection (Krebs 1999). We used EcoSim (Gotelli and Enstminger 2009) to estimate the number of species expected in Peterborough County had we caught 1000 weevils there during the same time periods as those in Algonquin and to compare species richness between the two regions.

# Results

In total, 5090 weevil specimens were collected from 10 subfamilies, 21 genera, and 26 species. The fragmented forest sites yielded 24 species, 11 of which were introduced,

and the continuous forest sites yielded five species, 3 of which were introduced.

More than 4000 individuals were captured in the Peterborough County pitfall traps (Table 1). Most individuals collected were of introduced species (95.1%) even though fewer than half the species were introduced (11 out of 24). The three dominant species were *Barypeithes pellucidus* Boheman (63.7% of total), *Otiorhynchus raucus* Fabricius (17.7%), and *Phyllobius oblongus* L. (6.1%). Of the 13 native species, *Hormorus undulatus* Uhler was the most abundant (3.2%). All other native species represented 0.6% of the specimens, or less. Five natives (*Anametis granulata* Say, *Rhyncolus brunneus* Mannerheim, *Grypus equiseti* Fabricius, *Listronotus sparsus* Say, and *Listronotus oregonensis* LeConte) were each represented by a single individual.

One thousand weevils from five species were caught in the Algonquin Park pitfall traps (Table 1). The three dominant species were all introduced and accounted for 99.8% of the total: *Sciaphilus asperatus* Bonsdorff (74%), *P. oblongus* (20%), and *Otiorhynchus ovatus* L. (5.8%). The two native species, *Nemocestes horni* Van Dyke and *Sirocalodes sericans* LeConte, were each represented by a single individual, and were not caught in the forest fragments. *Otiorhynchus ovatus*, *P. oblongus*, and *S. asperatus* were found in both forest types, and were collected every year. Five species (*H. undulatus*, *O. raucus*, *B. pellucidus*, *Polydrusus sericeus* Schaller, and *Trachyphloeus bifoveolatus* Beck) were only caught in the forest fragments, but were caught in all three years.

More than half of the species (57.7%) and 98.7% of the individuals caught in this study were from the subfamily Entiminae. Of these, 13 were flightless (86.7%) and nine were parthenogenetic (60%). All but one of the introduced species was from this subfamily. Seven out of 11 introduced entimines (63.6%) were parthenogenetic and flightless, three were bisexual and capable of flight (27.3%), and one was bisexual and flightless. The proportion of parthenogenetic introduced species was significantly greater than the proportion of parthenogenetic native species [7 out of 11 (63.6%) parthenogenetic introduced; 2 out of 15 (13.3%) parthenogenetic native; Fisher's exact test, $P = 0.01$]. The proportion of flightless introduced species was not significantly greater than the proportion of flightless native species [8 out of 11 (72.7%) flightless introduced; 6 out of 15 (40%) flightless native; Fisher's exact test, $P = 0.10$].

Peterborough County sites caught 2016 weevils from 18 species during the weeklong periods in late-May and mid-June that corresponded to Algonquin's sampling. Using the rarefaction method, in a random sample of 1000 weevils from this subsample of Peterborough County, we would expect to see between 13 and 18 species (95% confidence). The Peterborough County sites therefore have higher species richness than the Algonquin sites (1000 individuals from five species).

## Discussion

Contrary to our prediction, introduced weevils overwhelmingly dominated both the fragmented and continuously forested landscapes of central Ontario but the assemblages of the two regions were distinct and species richness was higher in the fragmented sites. Most of the weevils in both regions were flightless, but introduced species were more likely to be parthenogenetic.

TABLE 1. Subfamilies, status in North America (native or introduced), flight capability, mode of reproduction in North America, and known host plants of weevils (Coleoptera: Curculionidae) captured in pitfall traps in 22 hardwood forest fragments in Peterborough County, Ontario and 9 hardwood stands in Algonquin Provincial Park, Ontario.

| Subfamily[a] | Species | Peterborough | | | Algonquin | | Total |
|---|---|---|---|---|---|---|---|
| | | 2001 | 2003 | 2004 | 2006 | 2007 | |
| Dryophthorinae | *Sphenophorus minimus* Hart | | 19 | 5 | | | 24 |
| | *S. parvulus* Gyllenhal | | 10 | . | | | 10 |
| Erirhininae | *Grypus equiseti* Fabricius | | 1 | | | | 1 |
| Curculioninae | *Tychius picirostris* Germar | | 1 | 1 | | | 2 |
| Baridinae | *Stethobaris ovata* LeConte | | 3 | 1 | | | 4 |
| Ceutorhynchinae | *Sirocalodes sericans* LeConte | | | | | 1 | 1 |
| Cossoninae | *Rhyncolus brunneus* Mannerheim | | | 1 | | | 1 |
| Cryptorhynchinae | *Acalles carinatus* LeConte | | 15 | 3 | | | 18 |
| Cyclominae | *Listronotus oregonensis* LeConte | 1 | | | | | 1 |
| | *L. sparsus* Say | | 1 | | | | 1 |
| Entiminae | *Hormorus undulatus* Uhler | 55 | 51 | 25 | | | 131 |
| | *Otiorhynchus ovatus* L. | 12 | 38 | 14 | 5 | 53 | 122 |
| | *O. raucus* Fabricius | 90 | 256 | 378 | | | 724 |
| | *O. rugosostriatus* Goeze | 1 | | | | | 1 |
| | *O. singularis* L. | 2 | | | | | 2 |
| | *Nemocestes horni* Van Dyke | | | | | 1 | 1 |
| | *Phyllobius oblongus* L. | 90 | 124 | 37 | 133 | 67 | 451 |
| | *Polydrusus sericeus* Schaller | 4 | 1 | 4 | | | 9 |
| | *Barypeithes pellucidus* Boheman | 295 | 1799 | 512 | | | 2606 |
| | *Sciaphilus asperatus* Bonsdorff | 39 | 71 | 67 | 118 | 622 | 917 |
| | *Sitona lineelus* Bonsdorff | | 2 | | | | 2 |
| | *Cathormiocerus aristatus* Gyllenhal[c] | | 30 | 16 | | | 46 |
| | *Trachyphloeus bifoveolatus* Beck | 3 | 3 | 2 | | | 8 |
| | *Anametis granulata* Say | 1 | | | | | 1 |
| | *Phyxelis rigidus* Say | 1 | 3 | | | | 4 |
| Molytinae | *Conotrachelus posticatus* Boheman | | 2 | | | | 2 |
| | TOTAL | 594 | 2430 | 1066 | 256 | 744 | 5090 |

TABLE 1. continued...

| Species | Status[b] | Flight | Reproduction | Known Host Plants | Sources |
|---|---|---|---|---|---|
| *S. minimus* | Native | Yes | Sexual | Poaceae, Cyperaceae | Vaurie 1951 |
| *S. parvulus* | Native | Yes | Sexual | Poaceae, Cyperaceae | Vaurie 1951 |
| *G. equiseti* | Native | Yes | Sexual | Equisetaceae | Cawthra 1957; Anderson 2002 |
| *T. picirostris* | Introduced | Yes | Sexual | Fabaceae (*Trifolium*) | Anderson and Howden 1994 |
| *S. ovata* | Native | Yes | Sexual | Orchidaceae | Blatchley and Leng 1916; Howden 1988 |
| *S. sericans* | Native | Yes | Sexual | Papaveraceae, Fumariaceae | Anderson 2002; Korotyaev 2008 |
| *R. brunneus* | Native | Yes | Sexual | Downed woody debris | Anderson 1997; Anderson 2002 |
| *A. carinatus* | Native | No | Sexual | Downed woody debris | Anderson 2002; LaChowska et al. 2009 |
| *L. oregonensis* | Native | Yes | Sexual | Apiaceae | Campbell et al. 1989 |
| *L. sparsus* | Native | Yes | Sexual | Asteraceae, Chenopodiaceae | Boivin 1999; Anderson 2002 |
| *H. undulatus* | Native | No | Sexual | Liliaceae | Blatchley and Leng 1916; Champlain and Null 1921 |
| *O. ovatus* | Introduced | No | Asexual | Polyphagous | Takenouchi 1965; Anderson 2002 |
| *O. raucus* | Introduced | No | Asexual | Polyphagous | Anderson 2002 |
| *O. rugosostriatus* | Introduced | No | Asexual | Polyphagous | Wheeler 1999; Anderson 2002 |
| *O. singularis* | Introduced | No | Asexual | Polyphagous | Campbell et al. 1989 |
| *N. horni* | Native | No | Asexual | Polyphagous | Anderson 2002 |
| *P. oblongus* | Introduced | Yes | Sexual | Polyphagous | Pinski et al. 2005a |
| *P. sericeus* | Introduced | Yes | Sexual | Polyphagous | Pinski et al. 2005a |
| *B. pellucidus* | Introduced | No | Sexual | Polyphagous | Takenouchi 1965; Galford 1987 |
| *S. asperatus* | Introduced | No | Asexual | Polyphagous | Pinski et al. 2005a |
| *S. lineelus* | Native | No | Sexual | Polyphagous | Loan 1963 |
| *C. aristatus*[c] | Introduced | No | Asexual | Polyphagous | Piper et al. 2001 |
| *T. bifoveolatus* | Introduced | No | Asexual | Polyphagous | Brown 1965; Piper et al. 2001 |
| *A. granulata* | Native | No | Sexual | Polyphagous | Campbell et al. 1989; McLain 1998 |
| *P. rigidus* | Native | No | Asexual[d] | Brassicaceae, Rosaceae | Levesque and Levesque 1994; Shellhorn and Sork 1997 |
| *C. posticatus* | Native | Yes | Sexual | Fagaceae (*Quercus*) | Anderson 2002 |
| TOTAL | | | | | |

a) Subfamily classification based on Anderson 2002
b) Sources: McNamara 1991; Anderson 1997
c) Formerly *Trachyphloeus*
d) No males in Canadian Museum of Nature or Royal Ontario Museum collections

*Barypeithes pellucidus* dominated the forest fragments in Peterborough County while *S. asperatus* dominated the continuously forested sites in Algonquin Park. Both of these entimine weevils are flightless and polyphagous as larvae and adults (Witter and Fields 1977; Galford 1987; Anderson 2002) but *B. pellucidus* reproduces sexually (Takenouchi 1965), while *S. asperatus* reproduces through apomictic parthenogenesis (Suomalainen et al. 1987). Many parthenogenetic organisms are successful colonizers due to their abilities to continually propagate even at low population numbers, and to rapidly adapt because of more frequent random mutations (Ledig 1992; Langor et al. 2009). With asexual reproduction and a preference for *Acer saccharum* and other deciduous trees (Witter and Fields 1977), *S. asperatus* has been able to colonize not only the continuous hardwood forests of Algonquin Park, but also those in Michigan and Wisconsin (Werner and Raffa 2000; Pinski et al. 2005a; Coyle et al. 2008). It is a widespread species (McNamara 1991; Bright and Bouchard 2008) and has been found as far north as Iroquois Falls, Ontario (48° 45' N, 80° 41' W), and Edmonton, Alberta (53° 32' N, 113° 29' W; Bright and Bouchard 2008).

*Barypeithes pellucidus*, with a preferred diet that includes *Quercus rubra* (Fagaceae), *Aster spp.* (Asteraceae), *Medicago spp.* (Fabaceae), *Trifolium spp.* (Fabaceae), and weedy herbaceous plants (Galford 1987; Campbell et al. 1989) is the dominant species in the forest fragments in this study and in New York and Pennsylvania (Maerz et al. 2005). High numbers have been found in agricultural sites such as vineyards (Bouchard et al. 2005), berry plantations (Bomford and Vernon 2005), residential areas (Balsbaugh 1988) and continuous forests of Wisconsin and Michigan (Werner and Raffa 2000).

We suggest several explanations for why this adaptable colonizing species was absent from the Algonquin Park samples. Weevil abundance can vary considerably seasonally, from year to year, and from place to place (Balsbaugh 1988; Bouchard et al. 2005) and it is possible that *B. pellucidus* is established in the sites in Algonquin Park but the small sampling effort failed to detect them. In Quebec, Bouchard et al. (2005) caught over 1000 individuals of *B. pellucidus* in one vineyard but caught only 19 in another vineyard 30km away. They hypothesized that the high clay-content soils of the depauperate vineyard were less favourable to this species' pupation, but none of the soils in our study contained much clay (Webber et al. 1946; Gillespie and Acton 1981; Chambers et al. 1997). *Barypeithes pellucidus* are univoltine (Campbell et al. 1989). Adults usually emerge early in spring and disappear by mid-summer (Galford 1987; Maerz et al. 2005), and have only been found in the milder parts of Canada, such as southern British Columbia, around the Great Lakes, and in the Maritimes (Bright and Bouchard 2008). Specimens have been collected from as far north as Sault Sainte Marie, Ontario (46° 30' N, 84° 20' W; Takenouchi 1965) and Montreal, Quebec (45° 32' N, 73° 38' W; Bright and Bouchard 2008) but the frost-free periods in both these locations (120d and 140d, respectively), and in Peterborough County (124d), are much longer than in Algonquin (84d; Marsan 1990; Strickland 2006; Environment Canada 2008; MRCC 2009). The short frost-free period in Algonquin may be insufficient for one generation to find mates, lay eggs, and for the larvae of the next generation to hatch and grow to a sufficient size to survive the winter. If *B. pellucidus* is present in Algonquin Park, the combination of its flightlessness, sexual reproduction, and the short frost-free period, all likely contribute to limiting its numbers there.

*Otiorhynchus raucus*, like *B. pellucidus*, was abundant in Peterborough County,

but absent from the Algonquin Park samples. This species is flightless, polyphagous, and parthenogenetic in North America (Mazur 1992; Bright and Bouchard 2008), and has been found as far north as Calgary, Alberta (51° 07' N, 114° 19' W; Bright and Bouchard 2008). It was first reported in North America in 1936 at a nursery in Fonthill, Ontario (Hicks 1947), and the larvae are serious pests of garden vegetables, while adults feed on the foliage and shoots of fruit trees (Campbell et al. 1989). According to Mazur (1992), in Europe *O. raucus* is a common component in anthropogenic habitats such as urban parks, gardens, and roadsides, and it is probably absent from Algonquin Park due to the lack of cultivated plants on which it prefers to feed in both its native and introduced range.

*Phyllobius oblongus* was a dominant species in both landscapes. Unlike the aforementioned species, *P. oblongus* is capable of flight, and thus is a good disperser. It is established in continuous hardwood forests in the Great Lakes Region (Pinski et al. 2005a; Coyle et al. 2008) and in Nova Scotia (McCorquodale et al. 2005). Host plants include a wide variety of trees and shrubs, especially *Acer saccharum* (Witter and Fields 1977) and *Ostrya virginiana* (Pinski et al. 2005b). These tree species were common in both landscapes.

*Otiorhynchus ovatus* was present in both regions and in all five years, and was a dominant species in Algonquin. Commonly known as the strawberry root weevil, it is abundant, widely distributed, and can be found wherever plants occur (Bright and Bouchard 2008). It is flightless, parthenogenetic, extremely fecund, and has a very broad range of hosts, including conifers (Warner and Negley 1976; Campbell et al. 1989). This broad niche and the capability of overwintering as adults or larvae (Campbell et al. 1989), have likely facilitated *O. ovatus'* ability to colonize as far north as Fairbanks, Alaska (64° 50' N, 147° 38' W; Bright and Bouchard 2008). Why it was collected less frequently in the forest fragments than its congener *O. raucus* is unknown. *Otiorhynchus raucus* (5.5 to 7.5 mm) is larger than *O. ovatus* (4 to 5.5 mm; Bright and Bouchard 2008) and since pitfalls select for larger, more active individuals (Baars 1979), the high catches of *O. raucus* may not reflect the true proportions of these two species.

The only introduced weevil species caught in this study not in the subfamily Entiminae was *Tychius picirostris* Fabricius (subfamily Curculioninae). Commonly known as the clover-seed weevil, its larvae feed inside the reproductive structures of naturalized and cultivated clovers (*Trifolium spp.*; Anderson and Howden 1994; Anderson 2002). Though there are a few species of clover native to Ontario (e.g. *T. reflexum*), most are introduced from Europe (e.g. *T. repens* and *T. pratens*), and have been spread throughout the continent for their use as forage and in crop rotation (Taylor 1985; Voss 1985). Majka et al. (2007) suggest *T. picirostris* was introduced to North America in dry ballast, and with the ability to fly and the widespread distribution of its host plants (i.e. introduced clovers), it has become established throughout the continent (Anderson and Howden 1994).

*Hormorus undulatus* was the only abundant native weevil species captured in this study, and it was only caught in the Peterborough sites. Little is known of this entimine species beyond that it reproduces sexually, is flightless, and has been found on members of the Liliaceae family (*Convallaria, Maianthemum* and *Polygonatum*; Blatchley and Leng 1916; Champlain and Knull 1921). In Canada, it has been recorded as far north as Wawa, Ontario (47° 59' N, 84° 46' W; Bright and Bouchard 2008), and three were collected from raspberry (*Rubus idaeus*) in a Quebec plantation (Levesque and Levesque 1994). A few individuals

were collected in continuous hardwood forests in the Great Lakes Region compared to the thousands of introduced specimens (Coyle et al. 2008). Though sampling was not as intensive in Algonquin Park as it was in Peterborough County, the absence of *H. undulatus* from the Park's samples indicates that it is not an abundant species there. If it ever had been a significant component of the weevil community in this forest and those elsewhere, it is possible that the competitive abilities of the invasive European species already mentioned have displaced them. The short growing season may also have prevented *H. undulatus* from establishing in Algonquin Park and may explain the substantially lower species richness of the weevil communities of the park as compared to the more southerly forest fragments.

All parthenogenetic species caught in this study were flightless and polyphagous. With parthenogenetic reproduction and a polyphagous diet, these weevils do not need to find mates nor travel far to find food. The high proportion of introduced species that were parthenogenetic (63.6%) emphasizes the superior colonizing ability of these flightless weevils over flightless sexual species like *B. pellucidus*. The proportion of flightless introduced species (72.7%), however, was not significantly greater than the proportion of flightless native species (40%), which suggests that flightlessness alone does not affect colonizing ability. Therefore the polyphagous diets of entimines, in combination with either parthenogenetic reproduction or the ability to fly, have made these introduced weevils dominate the forested sites of this study.

Species richness was lower in the continuous forest sites than in the forest fragments. We found only five species in 1000 individuals in Algonquin, whereas we would expect 13 to 18 species in a same-sized sample from Peterborough County for the same time period. With three common species in Peterborough County (*B. pellucidus*, *O. raucus*, and *H. undulatus*) all seeming to be absent from Algonquin Park, it is likely that the shorter frost-free period, as well as the lack of agricultural and anthropogenic habitats are limiting others species as well.

This is the first report of *Sirocalodes sericans* for Ontario. Though it is generally distributed in the western and southern regions of the United States, in Canada it has only been documented in Manitoba (McNamara 1991; Anderson 2002). Other *Sirocalodes* species are associated with Papaveraceae and Fumariaceae, with larvae mining the stems or crowns of the host plants (Anderson 2002). *Dicentra cucullaria* (Fumariaceae) is a common spring ephemeral in northern hardwood forests (Walton and Hufford 1994), and is a possible host for this weevil. Further targeted sampling around this plant might help to elucidate more of this species' biology.

Pitfall traps are useful in assessing relative abundance of invertebrates active at the ground level, and are the most efficient method to assess ground-dwelling invertebrate communities (Prasifka et al. 2007). Further research on the weevil communities in these areas would benefit from additional sampling techniques such as flight-intercept traps, emergence traps, and sweep-netting.

The life histories and effects of invasive weevils are thoroughly studied in agricultural systems (e.g. *Otiorhynchus sulcatus* Fabricius; Moorhouse et al. 1992) because of the economic damage they can cause, but forest-invaders are poorly understood. We lack information on native weevil assemblages in forests prior to the invasions (Pinski et al. 2005a) and studying the tolerances and below-ground herbivory of introduced larval entimines is difficult (Coyle et al. 2008). There is ample scope for further study of the

functional role of these adaptable insects in our forested ecosystems.

## Acknowledgements

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# DISCOVERY OF THE WESTERN PALEARCTIC BEE, *MEGACHILE (PSEUDOMEGACHILE) ERICETORUM* (HYMENOPTERA: MEGACHILIDAE), IN ONTARIO, CANADA

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**Scientific Note**                        *J. ent. Soc. Ont.* 141: 85-92

The indigenous bee fauna of North America north of Mexico contains approximately 3500 described species (Ascher and Pickering 2010), but nearly 30 exotic species of Old World origin are published as established (Cane 2003; Committee on the Status of Pollinators in North America 2007). A few of these introduced species have a long history in North America. The first was the honey bee, *Apis mellifera* L., brought with European settlers in the 1620's (Crane 1999; Horn 2005) for honey and wax production, roles now overshadowed in importance by pollination services (Free 1993; Delaplane and Mayer 2000). Other, albeit very few, bee species have been purposely introduced into North America for evaluation as crop pollinators (e.g., Torchio and Asensio 1985; Batra 2003), though none of these species are used commercially. Most bee introductions have been accidental. Brown (1950) and Lindroth (1957) theorized that many introduced insect species may have arrived in the New World through the importation of dry ballast (e.g., rock, sand, soil). The earliest bee introductions likely included the ground-nesting species *Andrena wilkella* (Kirby), which has been in eastern North America since the 1800's (Malloch 1918), and *Lasioglossum leucozonium* (Schrank). *Lasioglossum leucozonium* was only recently determined to be an introduced species (Giles and Ascher 2006; Zayed et al. 2007), and not naturally Holarctic in distribution as previously assumed (McGinley 1986). The North American population(s) may have established from a single mated female (Zayed et al. 2007). These and the few other introduced ground-nesting bee species may have been introduced via ballast from ships in eastern North America (Giles and Ascher 2006).

Most successful introductions of bees (ca. 80%) have involved cavity-nesting species (Cane 2003; Committee on the Status of Pollinators in North America 2007), those nesting in pre-existing or easily excavated cavities, such as in hollow or pithy plant stems or beetle burrows in wood (Michener 2007). The alfalfa leafcutter bee, *Megachile rotundata*

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(F.), has been in North America since at least the 1930's (Cane 2003) and is now widespread across the United States and southern Canada, as far east as Nova Scotia (Sheffield et al. 2008), and two additional species of the subgenus *Eutricharaea* Thomson are also widely established. Three additional cavity-nesting megachilid bees, *Megachile sculpturalis* Smith, *Anthidium manicatum* L., and *A. oblongatum* (Illiger) are rapidly spreading in North America (Paiero and Buck 2004; Hinojosa-Díaz 2008; Zavortink and Shanks 2008; Gibbs and Sheffield 2009; Tonietto and Ascher 2009). Several species only recently detected in North America, such as *M. sculpturalis* (Magnum and Brooks 1997) and *Hylaeus hyalinatus* Smith (Ascher 2001), are now widely distributed and locally abundant members of the North American fauna. Many introduced cavity-nesting species do very well in urban settings (Matteson et al. 2008). For example, *Chelostoma campanularum* (Kirby), a recent arrival in Canada (Buck et al. 2006), is now relatively common in Ontario in the cities of Guelph, St. Catharines, and Toronto. Urban settings can support introduced bee species due to the presence of introduced plant species including floral hosts also visited in their native ranges (Hanley and Goulson 2003; Matteson et al. 2008; Gibbs and Sheffield 2009).

Invasive species are one of the biggest threats to regional biodiversity (Wilson 1999; Chivian and Bernstein 2008). Although introduced bee species account for less than 1% of the species in North America, they often constitute much larger proportions of surveyed faunas (calculations exclude *Apis*): 15% in Grixti and Packer (2006); 29% in Sheffield (2006); 27% in Matteson et al. (2008); and 8% in Tuell et al. (2009). Additionally, a recent survey in Guelph, ON found 12.5% of all bees captured in pan traps to be introduced species (M. Horn, unpublished data).

Considering that some introduced bee species are thought to disrupt local indigenous bee populations, and potentially pollination, through competition for floral (e.g. Paini 2004; Paini and Roberts 2005) and/or nesting resources (Barthell et al. 1998), it is especially important to note their presence and monitor their establishment (Cane 2003). It is also important to establish patterns of floral use, since many introduced species share floral resources with native species, especially in urban settings (Matteson et al. 2008) and agricultural settings that may have limited native floral resources.

The purpose of this note is to report the discovery in southern Ontario of *Megachile ericetorum* Lepeletier, a Western Palearctic bee species new to the Western Hemisphere. Its biology and diagnostic characters are briefly summarized, and methods for monitoring its potential establishment are discussed.

### *Megachile (Pseudomegachile) ericetorum* Lepeletier, 1841

*Megachile ericetorum* is wide-ranging in the Old World, occurring throughout most of Europe (excluding western Scandinavia), Asia Minor, the Caucasus, Central Asia, western North Africa, and Syria (Westrich 1989; Özbek and van der Zanden 1994; Banaszak and Romasenko 1998). Like many members of the genus *Megachile* Latreille, this species nests in pre-existing cavities in canes or wood (Westrich 1989; Banaszak and Romasenko 1998). Females lack beveled cutting edges in the interspaces of the mandibular teeth (Fig. 1), as *Pseudomegachile* Friese and other members of *Chalicodoma sensu lato* (*Megachile* Group 2, as per Michener 2007) do not cut leaf sections for nest construction but instead use other materials such as plant resins, sand, and pebbles to construct nest partitions (Mitchell 1980; Westrich 1989; Snelling 1990; Banaszak and Romasenko 1998; Michener 2007).

FIGURE 1. Face of specimen of female *Megachile ericetorum* Lepeletier collected in St. Catharines, ON, Canada, showing 4-dentate mandibles without cutting edges.

Westrich (1989) indicates that this species is oligolectic on Fabaceae, mainly *Lotus* and *Lathyrus*; males have been collected on *Stachys*.

Although the subgenus *Pseudomegachile* is indigenous to the Old World, another introduced species, *M. (Pseudomegachile) lanata* (F.), is commonly collected in Florida (Leavenwood and Serrano 2005) and the West Indies (Genaro 1997). Sheffield et al. (in press) provide keys and full descriptions to distinguish *M. ericetorum* from other leafcutter bees in Canada, although at this time, evidence is lacking as to whether this species has established successfully. The female of *M. ericetorum* can be distinguished from most *Megachile* in Canada by the lack of cutting edges between the mandibular teeth (Fig. 1), excluding *M. sculpturalis* which is much larger (≥ 20mm) with much orange pubescence, and *M. angelarum* Cockerell and *M. campanulae* (Robertson), which are both slightly smaller than *M. ericetorum* and lack the single median apical tubercle on the clypeus of *M. ericetorum* (Fig. 1). Although the male has not yet been observed in Canada, males of *M. ericetorum* are distinguishable from all other *Megachile* in Canada, except *M. coquilletti* Cockerell, by the unmodified yellowish front tarsomeres; it differs from that species by lacking a lower triangular process on the mandible (Sheffield et al. in press).

*Megachile ericetorum* is currently only known in North America from a single female specimen (Fig. 2) collected on the Niagara Escarpment in St. Catharines, Ontario in 2003 (14.vii.2003; coll. Amy Rutgers) in a former farm field east of, and contiguous with, the Glenridge Quarry Naturalization Site (43.124, –79.237; elev. 170m), and bordered on the west by Highway 406. The Naturalization Site was formerly a limestone quarry and then a landfill, which was closed in 2001 and completely replanted by 2003, whereas the field in which the specimen was found belongs to Brock University and has remained more or less undisturbed for almost 50 years. Westrich (1989) indicated similar habitat use (i.e., calcareous grasslands) by this species in Europe. The habitat in which the specimen was
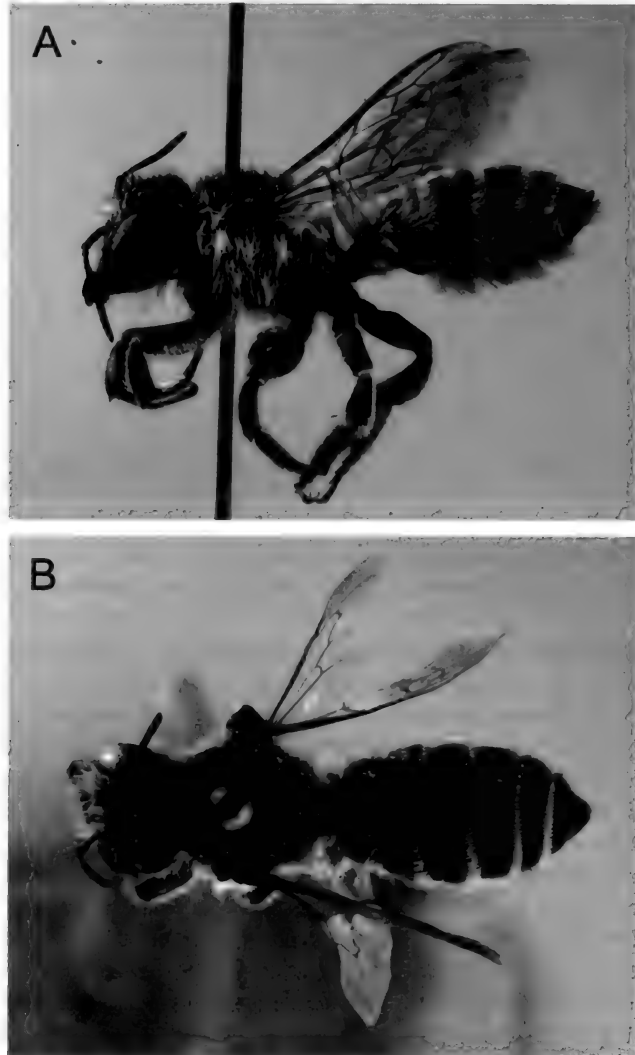
FIGURE 2. Female *Megachile ericetorum* Lepeletier, A) lateral and B) dorsal view. Specimen collected in St. Catharines, ON, Canada.

found and the method by which it was collected (pan-trapping) suggest that this species may have had the opportunity to establish in the area because the site is directly adjacent to a former landfill. This bee species could have been transported to the area in discarded lumber, for instance in wooden skids commonly used in international shipping. St. Catharines is part of the major shipping route for international materials arriving into Canada and the United States, and is < 20 km north of the United States border. Major seaports offer many opportunities for introduced species (Majka and LeSage 2006), and this region has a long history of commercial sea traffic. Several cavity-nesting species have been intercepted at

such ports of entry (Cane 2003), although they may not always have the opportunity to establish.

Since *M. ericetorum* has been in Canada at least since 2003, monitoring its establishment and spread should be done (Cane 2003). Ultimately, modeling its potential range in North America based on habitat suitability (e.g., Hinojosa-Díaz et al. 2005) may indicate if it has the ability to become widespread across many ecozones, as in its native range. Trap-nest surveys (e.g., Fye 1965; Krombein 1967; Sheffield et al. 2008) would provide a means of monitoring the establishment of this species in North America, as well as the possible displacement of native species (Barthell et al. 1998). Males of *M. ericetorum*, like those of the introduced *Anthidium manicatum* (Severinghaus et al. 1981; Wirtz et al. 1988), aggressively defend territories (Hass 1960). This behaviour should make the species stand out among the native *Megachile* species, potentially assisting in documenting its spread.

## Acknowledgements

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# ERRATUM

L. Timms. 2009. Growing pains: How the birth of the Entomological Society of Canada affected the identity of the Entomological Society of Ontario. The Journal of the Entomological Society of Ontario 140: 49-56.

The page numbers published for this manuscript in JESO 140 were incorrect. The correct reference is:

L. Timms. 2009. Growing pains: How the birth of the Entomological Society of Canada affected the identity of the Entomological Society of Ontario. The Journal of the Entomological Society of Ontario 140: **46-53.**

Below is how the title should appear. The editor apologizes for this error.

## GROWING PAINS: HOW THE BIRTH OF THE ENTOMOLOGICAL SOCIETY OF CANADA AFFECTED THE IDENTITY OF THE ENTOMOLOGICAL SOCIETY OF ONTARIO

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# CONTENTS